THE GLASS INDUSTRY

VOLUME 32, NUMBER 5, MAY, 1951

THE GLASS DIVISION PROGRAM AT CHICAGO

THE 53rd Annual Meeting of the American Ceramic Society was held at the Palmer House, Chicago, Illinois, April 22-26. This meeting was honored by a number of distinguished guests. Two well-known English glass technologists, R. W. Douglas, of General Electric Ltd., and Dr. H. Cole, of Pilkington Brothers Ltd., were in attendance. Fifteen engineers, foremen, and supervisors of various French glass companies were also present. They represented such branches of the industry as plate glass, flat glass, containers, etc. and were visiting plants in the United States to observe modern production methods, techniques, and labor relations, as well as new and improved products of American industry. They planned to stay for a six weeks' tour under the auspices of E.C.A.

H. H. Holscher, Owens-Illinois Glass Company, presided as Chairman except for sessions where F. L. Bishop, American Window Glass Company, C. E. Leberknight, Kopp Glass Works, or F. V. Tooley, University of Illinois, presided.

The first paper was presented by H. R. Lillie, Corning Glass Works, on the subject "A Method of Measuring Flow Point of Glass". A new approach was presented for providing a reference point at a temperature considerably above the softening point. Such a measurement is desirable for glasses that are to be used in reworking.

An apparatus and procedure are described by which a fiber elongation test indicates the temperature at which a glass attains a substantially fixed viscosity level estimated at 7×10^4 poises. A short section of a glass fiber (about 0.65 mm. diameter) is heated under specified conditions of load and heat application until it draws down to a thread. The temperature is inferred from the time required, and the apparatus is designed to automatically register the time to a least count of 0.01 sec. When properly standardized with a known glass, the precision of the test is equivalent to about 1°C. for soft glasses and about 5°C. for hard glasses.

The paper provided considerable discussion, and A. Q. Tool, formerly of National Bureau of Standards, remarked that it would be highly desirable to express such properties not as a point, but as a temperature range. S. R. Scholes suggested that they be called the "Lillie Point". This method will no doubt afford considerable application in the future as an aid in evaluating special glasses.

The second paper by L. C. Hoffman and W. A. Weyl, Pennsylvania State College, treated the subject, "Further Contribution to the Data on the Low Temperature Viscosity of Glass," and was presented by the senior author. A method formerly developed by Poole was used and further useful data in this field were compiled.

Sodium was replaced by potassium in a series of alkali-magnesia, alkali-barium, and alkali-copper silicate glasses. As the K_2O gradually replaced Na_2O, the viscosity passed through a strong minimum in the alkali-copper silicate glass, a weak minimum in the alkali-barium silicate glass and no minimum in the alkali-magnesia silicate glass. The substitution of copper and cobalt for magnesia in an alkali-magnesia borate glass showed only a moderate lowering of viscosity.

A paper from the National Bureau of Standards, "Density and Viscosity of Binary Alkali Silicates", by Leo Shartsis, S. Spinner, and Webster Capps was presented by Webster Capps. This paper was a definite contibution to the properties of glass at high temperatures. Such properties, always difficult to measure, are of extreme practical importance.

The densities and viscosities of melts in the systems Li_2O-SiO_2, Na_2O-SiO_2, and K_2O-SiO_2 were measured with a restrained sphere apparatus over the temperature range 1000° to 1400°C. Whereas at room temperature the density in each system increases with alkali content, at high temperatures the density decreases with alkali content, showing that the higher the alkali content the greater the thermal expansivity. Volume expansivity was calculated from the change of density with temperature. On a mole basis the volume expansivity of the potassium silicates in the molten state is greater than that of the sodium and lithium silicates with little distinction between the last two.

Another paper involving high temperature measurements on glass was presented by D. A. McGraw, Owens-Illinois Glass Company. The paper, "A Method for Determining Young's Modulus of Glass", presented a method for obtaining a very difficult measurement by the clever adaptation of a suitable extensometer and oscillograph circuit.

The method described in this paper provides a means of measuring the Young's Modulus of such glasses which is applicable from room temperature to 1250° to 1300°F. The sample, a cylinder of glass encased in a thin-walled metal tube, is mounted vertically in a furnace and bent as a cantilever beam by horizontal application of load at the top of the sample. The instantaneous deflection of the composite rod is measured and recorded by a suitable extensometer and oscillograph circuit. Young's Modulus is calculated from the difference between the load-deflection characteristics of the composite sample and those of an empty tube of the same metal. Data are presented for three soda-lime-silica glasses in the range 75° to 1300°F.

The next paper, "A Modified Ice Calorimeter for Measuring Specific Heats of Glass", by J. R. Johnson, and E. C. Montgomery, University of Texas, was presented by J. R. Johnson. Preliminary results were presented on specific heats utilizing a modification of the Bunsen ice calorimeter. The method described was simple and yet capable of giving precise measurements. The hope was expressed that the authors would obtain data on heat capacities of glasses over a broad range of temperatures.

Dr. Howard R. Lillie, Newly Elected President of the A.C.S.

Next, a series of highly theoretical papers was presented. The first, "The Effect of High Energy Radiation on the Absorption and Luminescence of Glasses and Crystals", by J. H. Schulman, R. J. Ginther, C. C. Klick, and E. W. Claffy, Naval Research Laboratory, Washington, D. C., was presented by J. H. Schulman. The paper was based upon the facts that certain solids and glasses are known to undergo photochemical changes when exposed to high energy radiation, and that these changes alter the absorption spectra and luminescent properties of the solid. The behavior of several crystalline and glassy materials was described and the phenomenon interpreted.

Another interesting paper, "Magnetism and the Structure of Glass", was presented by P. W. Selwood, Northwestern University. This technique, as developed by Professor Selwood, may be extremely helpful in determining the state of oxidation of certain transition elements such as manganese or iron.

Magnetic measurements made over a temperature range make it possible to calculate the magnetic moment which, for most para-magnetic ions, is directly related to the oxidation state. The plot of reciprocal susceptibility versus temperature gives an intercept on the temperature axis. This intercept is related to the state of aggregation. It is easy to decide on this basis whether, for instance, added nickel is present in true solid solution or as nickel oxide aggregates. Similarly, the development of ferromagnetism in reduced glasses containing nickel, iron, or cobalt is evidence for metal particle aggregates. The diffusion of such elements in glass may be followed.

The paper also proposed that certain metals such as silver, in a state of atomic subdivision, may be detected magnetically. This field of magnetic anisotropy, which has been applied successfully in organic chemical fields, may have important bearing in glass-chemistry fields.

The next paper in this series, "The Polarization of Ions and Temperature Dependence of Viscosity and Electrical Resistivity in Soda-Silica Glass", was given by S. W. Barber, Owens-Illinois Glass Company. It was an excellent paper presenting underlying theory involved in the dependence of viscosity and electrical resistivity of a soda silica glass (26 wt. % Na_2O) on temperature. The discussion centered mainly upon the polarization of the oxygen ion.

When temperature rises, the consequent increase in internuclear distances causes a decrease of the polarization of O^{-2} and this greatly weakens the Si^{+4}-O^{-2} interactions. From the ratio, β, between the activation energies for flow and electrical conductivity shown by Babcock to be constant for this glass at 5.39 between 814° and 1316°C., and from the coordinative structure of this glass it is concluded that the activation energy for flow is that for the mobility of O^{-2}. The constancy of β and the behavior of a broad selection of liquids, as shown by A. Bondi, lead to an easy procedure for estimating the heats and temperature-dependent entropies of activation at any point along the experimental log resistivity and log viscosity versus T^{-1} curves. Such estimates differ considerably from estimates based on the slopes and intercepts of tangents to the curves in the temperature range from 450° to 1400°C. in this glass.

The final paper in this group, "Anelasticity of Glass", by J. V. Fitzgerald, G. S. Bachman, and K. M. Laing, Pittsburgh Plate Glass Company, Creighton, Pa., was given by G. S. Bachman. This paper represented a continuation of the work presented by Fitzgerald at the Fall Glass Division Meeting in Toledo, Ohio. The work was based on on the application of theories formulated by C. Zener on the anelasticity of all real solids such as metals, plastics, ceramics, or glass.

At certain frequencies vibrational energy is strongly absorbed in glass. These regions of acoustic absorption can be understood in terms of underlying physical processes. Each peak in the acoustic spectrum, which is a plot of energy absorption versus vibrational frequency, denotes the presence of a relaxation process. Thermal diffusion (flow of heat), sodium ion diffusion (flow of material), the elastico-viscous effect (intergranular viscosity), and viscous flow (creep) are examples of relaxation phenomena observed in glass. The various relaxation processes cause glass to be imperfectly elastic or anelastic.

It was pointed out that anelasticity will become as valuable for glass technology as it now is for metallurgy. This theory has provided a basis for understanding the variation in elastic moduli of glass with temperature changes. The paper further pointed out that the fundamental nature of glass structure and the changes produced in it by heat treatment are also being studied on the basis of this theory. It was predicted that the acoustic spectrum will serve as a foundation for understanding structure, physical properties, and chemical nature of glasses in the future.

Two papers from the New York State College of Ceramics were well received. "The Role of Titania in Silica Glasses", by R. C. Turnbull and W. G. Lawrence, was given by W. G. Lawrence. A study of Na_2O-SiO_2-TiO_2 glasses revealed that Ti^{+4} ion exists in six-fold coordination. The conclusions were based on the determination of the partial molar refraction of TiO_2 in glasses as well as crystalline compounds. The other paper, "The Effect of Minor Additions on the Surface Tension of a Soda-Lime-Silica Glass," by R. C. Farnham and W. G. Lawrence, was presented by R. C. Farnham. Surface tension measurements were made on a soda-lime-silica base glass to which were added various increments of certain test oxides. The maximum bubble pressure method devised by Jaeger was employed, and a careful and painstaking technique was used by Miss Farnham. Values were obtained on some twenty test oxides at temperatures of 1350°, 1250°, 1150°, and 1050°C. In the discussion that followed, Dr. Cole of Pilkington Bros., England, revealed that their work had shown that gas-free glass had a higher surface tension than glass which was not free from gas.

A paper, "The Development of Low Dielectric Constant Glasses of the Borosilicate Type," by J. H. Plummer and W. A. Dunn, Glass Fibers, Inc., was quite inter-

C. E. Leberknight

esting. It was presented by W. A. Dunn and showed the effect of chemical composition on the dielectric loss of certain glasses. The research was done in cooperation with the U. S. Air Force, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio.

Successive lowering of the dielectric constant and loss tangent, measured at 10,000 megacycles, of a low alkali, high borosilicate glass composition by systematic variation in the formulation is described. Dielectric constants and loss tangents were reduced from 4.4 and 0.005 to values of 3.87 and 0.001, respectively. Effect on stability and chemical durability by changes in composition is also discussed.

Professor F. V. Tooley presented the next paper, "The Effect of Preparation Conditions on the Tensile Strength of Soda-Lime-Silica Glass Rods", by F. V. Tooley and G. F. Stockdale, University of Illinois. This work was a progress report related to a broad program of research on the proper preparation of specimens for tensile strength tests. A study was made of the drawing loads and temperature of draw for sample preparation. Both factors were shown to effect the tensile strengths of the specimens. It was suggested in the discussion of the paper that the temperature of drawing probably developed some surface devitrification of the rods and consequently affected their strength.

An unusual paper was presented by W. M. Conn, Rockhurst College, Kansas City, Mo. It was entitled "Solar Energy as a Means of Producing Glass Under Very Pure Conditions". Professor Conn described and presented illustrations of a sun furnace in which solar energy is concentrated in a very small area by means of parabolic mirrors to attain quite high temperatures.

The largest mirror which we have in operation has an aperture of 120 in. in a focal length of 34 in. It is equipped with a guiding mechanism to compensate for the rotation of the earth around its axis. Glass is produced from materials in the shape of solid slabs or blocks and from thin rods or cylinders. Examples are given for the recrystallization of molten materials and the formation of transition zones from the glass to the solid material.

The sun furnace has the advantage of utilizing no gas or fuels. However, it does not operate on cloudy days. The harnessing of this form of energy may be very important in the future. At such time all cloudy days will be declared holidays for the production department.

A series of three papers devoted to various phases of durability promoted considerable discussion. Professor Alexander Silverman, University of Pittsburgh, presented "Chemical Durability of Glass: Retrospect and Prospect." Numerous durability problems with which the glass industry is confronted were listed.

After briefly reviewing ancient glass and lessons to be derived from it, the possible changes of durability with chemical composition will be considered. In addition to ordinary durability requirements, special requirements for high temperatures, special radiations, vapor contents, various surface treatments, and other physical treatment will be indicated. The topic will be presented in retrospect with possible hints as to studies in prospect.

The next paper was presented by H. E. Simpson, New York State College of Ceramics. It was entitled, "Some Factors Involved in the Testing of the Surface Durability of Glass." This work represented a continuation of that reported at the Glass Division Meeting in Toledo.

Surface durability of flat glass was studied, after exposure of samples to alternate cycles of surface fogging and clearing under high humidity conditions. The total transmission and the amount of scattered light of the weathered samples were measured by means of a photoelectric haze meter, and the relative amount of scattering was taken as a measure of the amount of haze or surface deterioration.

By plotting the per cent haze developed versus the days exposure, the author presented a graphical picture of the breakdown of each glass. It was found that the glasses tended to become less durable with age and that this tendency was greatly influenced by the method of storage. Storage in dry-boxes with paper interleaves was shown to be a definite improvement. Surface durability tests were also made on samples in intimate contact. Comparison of surface durability tests with those of powder durability did not show a definite correlation. Grateful acknowledge was made to Libby-Owens-Ford Glass Co., American Window Glass Co., and Bausch and Lomb Optical Co. for cooperation in furnishing samples. There was considerable discussion and interest in the method of attack of the problem.

A paper, "The Surface of Sheet Glass," by F. L. Bishop and F. W. Mowrey, American Window Glass Company, Arnold, Pa., was presented by F. L. Bishop. This paper, which was enthusiastically received, was an attempt to study the durability problem in a practical way. Some excellent photomicrographs were shown which revealed the surface condition of sheet glass before and after accelerated weathering. Durability was correlated with such operating factors as melting, drawing, rate of cooling, etc. This paper also prompted considerable discussion and the hope that this type of work would be continued.

The technical program was concluded by the paper, "Investigation of the Adherence of Glass to Metals and Alloys", by R. C. Dartnel, H. V. Fairbanks, and W. A. Koehler, West Virginia University. This paper represented a continuation of a broad program of research involving the study of glass adherence to various metal alloys which has been in progress at West Virginia University for some time.

Several commercially pure metals and alloys plus a carbon-iron series were run for their adherence temperatures. It was found that as the per cent carbon in iron was increased, the adherence temperature was decreased. Heat treating of a modified brass sample decreased its adherence temperature. Persistence tests were run using tungsten, nickel, and Monel with clear and amber soda-lime glasses. The amber glass used gave higher persistence values than the clear soda-lime glass although the adherence temperatures checked very closely. Monel metal heated to 900°F. gave a persistence of over 800 molten glass contacts using amber glass at the rate of one glass contact per minute.

This excellent series of papers for the Glass Division was provided by the following committee: W. T. Gray, Chairman, Leeds and Northrup Co.; K. B. McAlpine, Pittsburgh Plate Glass Co.; W. H. Manring, Ball Bros. Co.

At the annual Business Meeting of the Section, the Fall Glass Division Meeting was announced for October 12 and 13, 1951, at Corning, N. Y. This meeting coincides with the 100th Anniversary of the Corning Glass Works.

Newly elected officers for the Division follows: *Trustee:* K. C. Lyon, Armstrong Cork Co., Lancaster, Pa.; *Chairman:* C. E. Leberknight, Kopp Glass, Inc., Pittsburgh, Pa.; *Vice-Chairman:* F. V. Tooley, Univ. of Ill., Urbana, Ill.; *Secretary:* F. L. Bishop, American Window Glass Co., Arnold, Pa.

VOLUME DILATOMETRY

Scientists of the National Bureau of Standards have found the simple, inexpensive volume dilatometer to be a valuable research tool, not only for obtaining data on volume coefficients of thermal expansion, but also for studying phase changes in solids and liquids. Continued application of volume dilatometry at the Bureau over the past 15 years has resulted in improvements in technique and in simplification of the apparatus to such an extent that accurate dilatometers can now be made and used in almost any small laboratory.

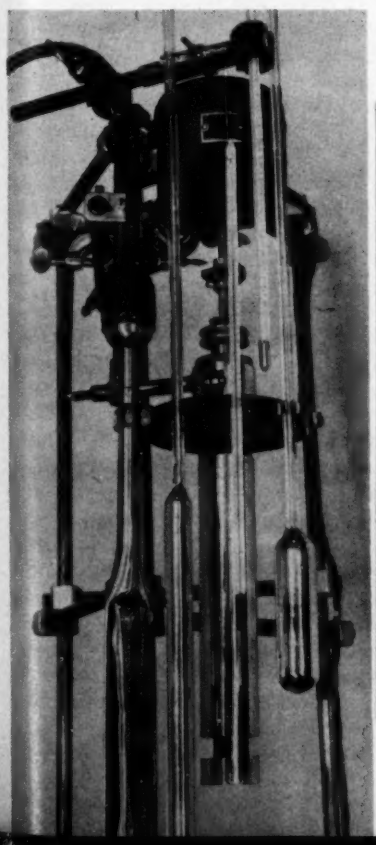
Linear dilatometers of various types have frequently been used to advantage in determining the expansivity of metals and other solid materials. They cannot, of course, give correct results for liquids or for other fluid materials. In these cases the volume dilatometer can be used successfully; it has been shown to have a precision of about 1 per cent.

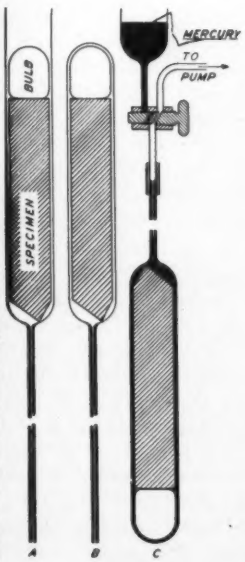
Primarily, the volume dilatometer measures the change of volume of a sample as it undergoes a change in temperature. Its secondary importance lies in the discovery of phase-changes and other transitions. Thus, if the density or volume of a substance is plotted as a function of the temperature, there will be anomalies in the otherwise smooth curve wherever there is a change of phase or other transition. These anomalies represent points at which a change occurs in the structure of the sample or in the types of motion by which it can absorb energy. They may or may not be accompanied by the release or absorption of heat.

Materials for the construction of the instrument consist of glass tubing of any convenient size and a calibrated glass capillary. The confining liquid may be mercury or any other substance which has a known expansivity and which will not react with the sample. Uniform heating is provided by means of a bath containing alcohol, water, or a high-boiling oil, depending on the range of temperature to be studied.

(*Continued on page* 261)

Note: For further technical details, see Volume Dilatometry, by Normal Bekkedahl, J. Research NBS *43*, 145 (1949) RP 2016.





(*Left*): Two dilatometers have been prepared and mounted on a circular rack for immersion in a water bath. From left to right the equipment includes a knifeblade heating element, a dilatometer, a stirring device operated by the motor above, a thermometer to record the temperature of the bath, an air thermometer above the level of the bath to record the dilatometer stem temperatures, and a second dilatometer. The size and shape of the samples (not visible because they are confined in mercury), determine the size and shape of the dilatometers. The instrument is heated by means of a bath (alcohol, water, or a liquid of higher boiling point), an expansion of the sample is indicated by a rise of mercury in the capillary. (*Center*): Several dilatometers are immersed in a water bath, along with a heating element, a heat control unit, a stirring device, and thermometers for both the bath and the air surrounding the stems of the instruments. Auxiliary equipment includes a Variac (left background), which controls the power supply to the heater, two boxes housing switches and fuses, a rheostat for controlling the speed of the stirrer (right background), and, in the left foreground, an electronic thermal regulator, incorporating a Thyratron relay. A 1-gallon Dewar flask serves as the bath container. (*Right*): Materials for constructing the dilatometer include a glass capillary of uniform bore, 2 mm, in inside diameter, and a glass tube 20 mm, in diameter. After the capillary has been calibrated, it is sealed to the 20 mm tube. The sample is introduced into the tube, and a glass bulb is added (A). This bulb, of the same material as the tube, is used to prevent overheating of the sample when the tube is sealed off (B). The completed dilatometer is then inverted and connected to a mercury reservoir and a vacuum pump (C), exhausted, and filled with mercury to a convenient level in the capillary.

SYMPOSIUM ON THE PHYSICAL CHEMISTRY OF GLASS

Chemists and Glassmen unite in discussion during the 119th National Meeting of the American Chemical Society

GLASS specialists from industry and physical chemists from universities spent a full day together discussing eight invited papers on the physical chemistry of glass during a Symposium sponsored by the Physical and Inorganic Chemistry Division of the American Chemical Society at the 119th National Meeting in Cleveland on April 10. Attendance varied during the day with a maximum of about three hundred. Fifty staunch regulars from the Glass Division of the American Ceramic Society stayed with the discussion all day. The chair recognized Dr. Howard Lillie of Corning Glass Works and President of the American Ceramic Society. The chairman and organizer of the Symposium, Dr. Norbert J. Kreidl, Chemical Research Director of Bausch and Lomb Optical Company, experimented in allowing two hours of discussion as compared to a little over three hours of speaking time in a full day session. It seems that the discussion periods were completely used without any artifice, indicative of the trend towards more selective and argumentative sessions in contradistinction to paper-inflated periods during some of the current meetings. In the general assembly, Procter and Gamble's Associate Director Richardson had courageously lashed out against such inflation which he believes is caused by the abuse of the interwoven interests of scientists in prestige and livelihood.

Foreign Contributions Add Interest

The Symposium was distinguished by the presence and presentations of two noted British glass technologists, H. Cole of Pilkington Bros. Ltd., and R. W. Douglas of the British General Electric Co. Ltd., which, incidentally, is not affiliated with the U. S. company of the same name. R. W. Douglas is also the Secretary of the British Society of Glass Technology. Both men have been presenting important and profound papers on the nature of glass through the British Society, but appeared here for the first time. Glass scientists throughout the country had an occasion to consult on matters of immediate interest as both Mr. Cole and Mr. Douglas visited widely scattered glass and solid state centers before and after the meeting.

The renowned Austrian physicist, Dr. A. Smekal, was unable to present his scheduled manuscript on polishing. In his absence a stimulating free translation of a letter containing the intentions of the speaker was rendered by Dr. Kreidl. A lively discussion was led by the excellent improvisation of Louis Rowe, American Optical Company, that included the news that the sequence of his five daughters had just been culminated by a son. This dual performance won him the biggest applause of the day.

Keynote Stresses New Physiochemical Approaches

Keynote to the Symposium was sounded in the introductory remarks of the Chairman. X-ray analysis and its interpretation by Goldschmidt, Zachariasen, and Warren so neatly replaced earlier speculation on the particle arrangement in conventional glass by objective information that for almost two decades glass technologists were delighted to play with the application of crystal chemistry to their problems. Only within the last few years has it been recognized that for continued progress a much broader variety of methods and interpretations is now wanted.

Right now, the intensity of solid state study has given emphasis to a parallel study of glass. Dr. Kreidl stated and illustrated the case by the National Research Council's Academy of Science book on transition in solids in which, among others, solid state scientist Smoluchowski and glass scientist Weyl collaborate.

The primary purpose of the Symposium was not to elicit original papers but to drag out for public exhibition and comparison some of the more promising new physiochemical approaches. At the same time, new research groups and distant countries were to be duly represented. The available material included the absorption of light, X-rays, neutrons, mechanical, and electrical waves; fluorescence and photochemistry, elasticity, photoelasticity, surface chemistry, the changes with time of viscosity, refraction, volume, and electrical properties; and, most recently, the responses to the magnetic field. Recent results of the application of such methods include improved concepts on the cause of coloration, the development of new infrared, X-ray, and neutron absorbing, as well as X-ray and infrared transmitting glasses, of glasses less prone to discoloration upon radiation, photosensitive glasses of thrilling properties, radiation detection glasses, the explanation of diffusion rates by sound absorption data, improved thermometer glasses, the chemical explanation of strength and fracture phenomena, control of properties, especially refractive index, the explanation by refraction data of glass formation by what had not been considered glass formers, and, last but not least, the startling discovery of isothermal volume changes of glasses at multiple rates and even opposite sign.

The combination of the desire to represent some of these topics, with some preference for newer work on newer subjects, and the good will of the representatives was to constitute the program of the Symposium.

Invitation to the Ceramic Society Meeting in Chicago

Dr. Kreidl invited those present to continue the debate on glass on its more usual meeting grounds at the Chicago meeting of the American Ceramic Society on April 23. He had arranged that several of the speakers would present their views in Chicago also or extend their presentation there. The British guests, while not presenting formal papers in Chicago, had kindly agreed to participate in the session there. Francis Flint, Hazel-Atlas Glass Company, created an intermediate forum be-

tween glass science and chemistry when he discovered that native cordials were dispensed at the French exhibition in a Cleveland hotel and some additional conversation on glass was thus extended into the late hours of the evening, between him, our British friends, and some enthusiasts.

SUMMARY OF PAPERS AND DISCUSSION

Glasses That Remember Gamma Radiation

Dr. J. Schulman and his collaborators at the Naval Research Laboratory in Washington presented evidence and showed attractive colored slides of the effect of high energy radiation (X or gamma rays) upon the color and fluorescence of glasses which thus becomes a measure of that high energy radiation. The mechanism is similar to that in radioluminescent crystals. However, the discussion showed that in glasses the effect is limited to few compositions, chiefly to the non-silica glasses that are capable to hold in solution much silver, the elemental state of which is obtained in this reaction.

Professor Rindone, of Penn State, described the similar but more time consuming experience with lower energy uv on silver silicate glasses.

Acoustical Spectrum Reveals Peaks of Absorption

G. S. Bachman gave an excellent presentation of the paper by Fitzgerald, Bachman, and Laing, Pittsburgh Plate Glass Company, on Anelasticity, as Dr. Fitzgerald was prevented from attending because of illness. The acoustical spectrum reveals peaks of absorption as does the optical spectrum. In this case the peaks can be understood in terms of relaxation processes. The most spectacular case is the mobility of the alkalies in the rigid assembly of the glass, and the evaluation corresponds to that of the speed of travel of alkali in diffusion processes studied by radioactive tracer methods. Potassium and sodium can be distinguished, and lithium will be investigated. The chilled and annealed glasses can be clearly separated in this analysis. In the discussion a fine point was an unknown peak that is not related to the alkali phenomenon. No peculiarity was found in glasses containing B_2O_3, the investigation remaining limited to 10% B_2O_3.

Magnetic Glass

It turned out that the two speakers on magnetism of glass had neither to agree nor disagree on anything. They appear to have selected different tools.

Dr. Selwood, of Northwestern University, believes that the measurement of the magnetic susceptibility of glass is an easy job and that the valency and aggregation of coloring ions in glass can be detected. His initial experiments presented facts about cobalt and nickel in glass that gave physiochemists handling crystals or solutions a nice parcel of new problems in their fields, it seemed.

H. Cole, of the Pilkington Glass Works, the first of the British guests, used the polarization of light in the magnetic field as a measure of the departure in glass of electronic configurations from the inert gas structure and, thus, of the nature of their bonding. He brings in an independent explanation of the existence of high lead containing glasses that agrees with that offered by workers on refraction: the inclination of the lead ion itself to lend itself to the formation of a vitreous material.

Both papers were discussed jointly and at a high level of scholarship. It seems that there is hope to study colored ions in the changed environments of phosphate and borate glasses; and, in England, much work is under way on iron glasses in which the magnetic susceptibility of 5.9 for Fe^{3+} was verified. Upon Dr. Schulman's question, Dr. Selwood also expressed optimism for the use of paramagnetic resonance.

Polishing

Dr. Smekal believes that abrasive particles under a certain size wear glass and other materials by a special mechanism of "cold melting". It is greatly hoped that the photographic material upon which the theory is based will be published soon. The peculiar property governing polishing efficiency from a merely physical viewpoint is called superhardness and Smekal is now prepared to determine this property on important materials.

Dr. L. Rowe of the American Optical Company led the discussion with an improvised talk on chemical factors. Since no abstract of his spontaneous remarks is available, a brief review of his views follows here.

It is hard to cover the chemical effects as well by academic analysis as the physical facts so ably presented by Smekal. However, they are vital from the viewpoint of speed and economy of production. The source and previous history of the polisher, as well as the coolant, can greatly vary the practical performance. When water is used it must be agreed that the part played by water in the interaction of polisher and glass is great. For this very reason the chemistry of the backing material cannot be neglected. As water enters the process, the capacity of the backing to hold water is significant. The action of water must at least be considered in the following phases: (1) Hydration of glass, (2) Adsorption of hydrated layers by polishers, (3) Transportation of hydrates to (a) Other parts of the glass surface and (b) into the suspension. Drags are considered functions of coagulation rather than particle size that is considered irrelevant up to 50 microns.

In the further discussion, rare earth polishers were considered 50-70% faster than rouge, but mechanical changes were said to affect polishing by 1000%. The previous history of rare earths also being important, it is not advisable to compare polishing efficiency of materials as such. It was mentioned that iron oxide particles of one micron added to rare earth particles of 20 microns slow up the process. Corundum of 1-3 microns fineness was said to polish ¼ as fast as rouge only, while dehydrated aluminum hydrate heated to 1400°F. will polish as fast as rouge.

Those participating in the discussion seemed to believe that, even in Smekal's "dry, physical process", water enters. Rowe, upon questioning, explained that polishing rates were measured by weight losses, which remain constant with time in the case of rouge, but not of calcined clay. The audience also agreed that some flow, like Smekal's "cold melting" takes place, but thought that the hydration must be considered in the process. Oxides still dominate experimentation on pol-

ishing and people curious about phosphates, fluorides, carbides could not be satisfied.

Acid Base Relations

Professor Audrieth, one of the leading U.S. chemists of the present time, believes that a return to the old-fashioned appraisal of basic and acid characteristics of constituents is justified in the light of bold modern generalizations on acidity. Constant readers of THE GLASS INDUSTRY remember Silverman's and Sun's interpretation of Lewis' electron pair theory. Professor Audrieth goes far beyond that stage starting from the electronic theory that defines bases as electron donors and acids as acceptors, and is able to define the "acidity" of cations as well as describe the necessary covalency of glass forming bonds in terms of the relative acidities in presence of oxygen. He introduced the specialized acid base theory for oxides of the Norweigan scientists Lux and Flood. Dr. Flood originally had hoped to be present at this meeting. It would be very interesting to have him as a future speaker on the subject. Many glass reactions become similar to polymerization and depolymerization reactions of plastics when Audrieth's approaches are used and the discussion centered on this point. The conversation became quite technical and people went as far as to wonder whether the proton in H_2SO_4 came from the water or the acid. Apparently this is to be followed by using deuterium for hydrogen.

Volume Changes with Time and Temperature

Little as it may seem at first, the changes of the volume of glass with time and temperature are right now one of the most fascinating fields of glass research. R. W. Douglas has merited great applause for his elegant and scholastic attacks on the problem. His measurement clearly reveals several mechanisms causing such volume changes and he has been able to demonstrate their normalcy in substances as simple as pure SiO_2, the experimentation being by no means simple. As in certain temperature areas for water, the density of glass can increase with temperature as more ordered open structures are in equilibrium at lower temperature. The mechanism of attaining equilibrium volumes of glass—so important in fine annealing and in sealing—is then discussed from three viewpoints: (1) ordering from randomness, as in most liquids, (2) the structural factor that at close atomic distances open configurations with directed forces are assumed, and (3) a tendency towards unmixing in complex glasses, e.g., the possible preference of alkali ions in borosilicates for boron surroundings.

Expansion experiments with silica of different thermal history give complex curves as the rate of (1) and (2) phenomena is different. This is originally derived from the complex experience in sealing.

In the discussion, our American experts on sealing and expansion admired the experimental skill of the work, especially the overcoming of devitrification in the annealed samples. Polishing before and after the experiment gave satisfactory quality to such samples. It appears that crystallization always started at the surface and it was interesting to hear that any mistake should have similated a decrease rather than the observed increase or density.

The Soft Nature of B_2O_3 Glass

The most radical departure, in form, from crystal chemistry approaches was the revised behavior of B_2O_3 presented by Dr. K. Fajans of the University of Michigan and S. Barber of Owens-Illinois Glass Company. Professor Warren had patiently educated us to think of boron coordinating three oxygens in triangular form which in the presence of alkali might transform to four-fold coordination. In a pleasing manner, this picture had cleared up the many mysteries of the behavior of B_2O_3 in glass such as the maxima or minima in properties sometimes termed the boron oxide anomaly. Fajans and Barber have re-examined a mass of physical property data of B_2O_3—and subsequently of borosilicate glasses—and do not feel like interpreting them in terms of "coordinative" structures like Warren's. Instead, they find evidence at low temperature of what they like to label a "molecular" structure comparable to (B_4O_6) molecules, the bonds within such molecules being strong, those between molecules weak. Above 300°C. the structure changes to the more "coordinative" type, i.e., one where various B-O distances and bonds become comparable. This picture is useful and reasonable. In particular, it eliminates needs for artificial assumptions on structural changes with temperature. It was also stimulating that the form of presentation was radical, although the discussion—in the opinion of the reviewer, correctly—showed that the approach supplements rather than contradicts the present, if not the original, state of glass science based on X-ray evidence. On close examination, the protagonists in the battle of terms are often nearer to each other than is evident in the heat of the battle. Two points of the discussion were of particular interest. First, annealing was shown to increase the "molecular" (ordered, diversified) structure. Second, the rather radical word "molecular" structure was explained to mean quantitative differences such as in X_4O_6 are represented by distances of X-O of 2.01 within, 2.78 between molecules.

The Chairman terminated the discussion as it became involved in bond terminology expressing his hope to keep some disagreement for the purpose of the enjoyment of future discussion.

Introductory remarks and author's abstracts by Dr. Kreidl follow:

The increased intensity in the scientific discussion of glass is associated with the general interest in solid state physics and chemistry today. This association is documented, e.g., by a book on transitions in solids just being issued by the National Research Council of the Academy of Science, in which Smoluchowski and other solid state men collaborate with a glass scientist, Weyl, on changes in ionic arrangement with temperature, pressure, and the external electrical field.

This parallelism of interest does not signify one in material constitution. Rather, physical chemists begin to realize that the condition of glass in the rigid form offers a unique opportunity to study high temperature equilibria at rest. And Dr. Douglas of England, who is with us today, has correlated his observations on glass with the liquid rather than the solid state.

Crystals when subjected to changes in heat, pressure, or external field may change into allotropic modifications. Glasses, having no long range order, undergo re-

lated but less defined changes in ionic arrangement continuously and there need not be any abrupt changes in properties due to cooperative maneuvers.

The much greater tolerance for rearrangement due to lack of long range order has one consequence that should be of particular interest to solid state chemists. It eliminates the frequency of grave disturbances or spots of high potential energy that is now considered a common feature of solids. Glass is uniquely poor in missing or foreign ions, holes, traps, dislocations, etc.

Conversely, glass offers the opportunity to introduce into a rigid structure practically all known chemical elements, each ion having a great chance to select its own environment (short range order).

From supercooled liquids—or at least "ordinary" super-cooled liquids which are definable by composition, pressure, and temperature—glass differs by the great sensitivity to thermal history.

In relation to the present decrease of emphasis of the solid-like properties of glass, one reminiscence from the earlier debate may have some appeal. At the 1925 Symposium, Le Chatelier proposed approaches much in accord with today's program: radiation absorption and magnetism.

However, progress on this suggestion was impossible before X-ray analysis provided objective and absolute data on the particle arrangement in conventional glasses (Goldschmidt, Zachariasen, Warren). This period was characterized by our widespread application of crystal chemistry to glass problems (Pincus, Taylor, Weyl-K., Dietzel, etc.).

On this sound basis, we are now to apply a much broader variety of physicochemical methods and aspects.

The combination of the desire to represent some of these topics, with some preference for newer participants in newer studies, and the good will of some of the representatives is the constituent of today's program.

I would like to invite all of you to continue the debate in our more common meeting grounds, the Glass Division and the Basic Science Divisions of the American Ceramic Society, where some of our speakers today will present and discuss these and other topics at our next meeting in Chicago in the week of April 23. This is the occasion to welcome our President-Elect, Dr. H. Lillie of Corning, as our guest here today, who happens to be himself prominently engaged in the development of what was sketched.

I am disappointed to announce that our friend, Dr. A. Smekal, was unable to attend.

Abstracts

The Effect of High Energy Radiation on the Absorption and Luminescence of Glasses and Crystals. *By James H. Schulman, Robert J. Ginther, Clifford C. Klick, and Esther W. Claffy, Crystal Branch, Metallurgy Division, Naval Research Laboratory, Washington, D. C.*

The absorption of radiant energy by matter can result in dissipation of the absorbed energy as heat, in reradiation of the absorbed energy as luminescence, or in production of photochemical changes in the absorbing material. The occurrence of photochemical changes on irradiation of a solid is most frequently manifested by a change in its absorption spectrum as, for example, in the formation of F-bands by treatment of the alkali halides with x-rays or gamma-rays. A number of crystals and glasses are of particular interest in that they undergo photochemical changes on exposure to high energy radiation that alter not only their absorption spectra but their luminescent properties as well. The behavior of a number of such crystalline and glassy systems will be described, and an interpretation of the phenomenon will be proposed for some of the simpler cases.

Anelasticity of Glass. *By J. V. Fitzgerald, G. S. Bachman, and K. M. Laing, Research Laboratories, Pittsburgh Plate Glass Co., Creighton, Pa.*

At certain frequencies, vibrational energy is strongly absorbed in glass. These regions of acoustic absorption can be understood in terms of underlying physical processes. Each peak in the acoustic spectrum, which is a plot of energy absorption versus vibrational frequency, denotes the presence of a relaxation process. Thermal diffusion (flow of heat), sodium ion diffusion (flow of material), the elasticoviscous effect (intergranular viscosity), and viscous flow (creep) are examples of relaxation phenomena observed in glass. The various relaxation processes cause glass to be imperfectly elastic, or anelastic. C. Zener has formulated a theory of anelasticity to describe this behavior, which is typical of all real solids, whether metals, plastics, ceramics, or glass. Anelasticity must, therefore, become a valuable tool for glass technology just as it now is for metallurgy.

Already the variation of the elastic moduli of glass with temperature can be understood. Many delayed elastic effects can be explained in terms of ion diffusion. Insight is obtained into the fundamental nature of glass structure and the changes produced in it by heat treatment. Electrical after effects such as the residual charge become explainable. The precipitation of crystalline phases in glass can be followed even before the precipitated phase is visible. The acoustic spectrum serves as a basis for understanding the structure and the physical and chemical properties of glass.

Magnetism and the Structure of Glass. *By P. W. Selwood, Northwestern University, Evanston, Ill.*

The few studies which have been made on the magnetic susceptibility of glasses show that the chief application of these methods is to find the oxidation state and state of aggregation of transition group elements such as manganese or iron. Magnetic measurements on glass are not difficult. If they are made over a temperature range, it becomes possible to calculate the magnetic moment which is, for the most paramagnetic ions, directly related to the oxidation state. The plot of reciprocal susceptibility versus temperature gives an intercept on the temperature axis. This intercept is related to the state of aggregation. It is easy to decide on this basis whether, for instance, added nickel is present in true solid solution or as nickel oxide aggregates. Similarly the development of ferromagnetism in reduced glasses containing nickel, iron, or cobalt, is evidence for metal particle aggregates. The diffusion of such elements in glass may be followed. It is closely related to the better known phenomena in solid solution of, say, chromia in alumina.

There is some possibility that certain metals, such as silver, in a state of atomic subdivision may be detected magnetically. The field of magnetic anisotropy, which is yielding interesting results in high polymer chemistry, would seem to be worth exploring.

Magneto-Optic Properties and Constitution of Glass. *By H. Cole, Research Laboratories, Pilkington Brothers, Ltd., St. Helens, Lancashire, England.*

For most substances, including glasses, the Verdet constant, V, of the substance at a wave length λ is related to the dispersion, $dn/d\lambda$, at the same wave length, according to the modified Becquerel equation.

$$V = \gamma \frac{e}{2mc^2} \lambda \frac{dn}{d\lambda}$$

The value of γ lies between unity and zero, depending upon the spectroscopic ground-state of the component atoms of the substance. The deviation of the value of γ from unity indicates the extent to which the electronic configura-

tion of the atoms or ions concerned departs from the inert gas structure, with an S-ground state. Because the electronic configuration is governed by the type of chemical bonding exhibited by the atoms or ions, it is possible to relate the value of γ with bond type.

The amount of covalent bond character associated with particular atoms in glass may be regarded as a measure of the degree of participation of these atoms in the glass structure.

Measurements made on a series of lead glasses indicate that, particularly in the dense flints, the lead atoms are probably present as Pb^{IV} quadricovalently bonded network-forming atoms. Similarly, results from barium-containing glasses show that this element can participate to a considerable extent in the glass network.

It is suggested that the magneto-optic method provides a most useful tool for the study of glass structure and a plan of future work in this aspect is put forward.

Physical Chemistry of Glass Polishing. *By A. Smekal, Physics Department, University of Graz, Austria.*

The process of polishing is fundamentally different from that of grinding. It consists in crack-free quasiplastic displacements of glass substance. The considerable amount of work absorbed by this displacement corresponds to that needed to overcome continuously the full strength of chemical bonding. A notable part of this work is rendered immediately within the displaced matter in the form of heat which contributes as a secondary agent to the smoothening of the glass surface. These processes are purely physical in nature only as long as the chemical reactions initiated by the movements of particles of molecular dimensions and of the polishing fluids are neglected—e.g., in the case of diamond powder in the absence of a reactive fluid. Work and time can be reduced if abrasives (including glass) form eutectic melts on small contact areas. Polishing fluids equalize temperature differences, provide for particle transport and distribution, and may complicate the chemical processes involved in the entire polishing mechanism. On this basis the empirical facts of glass polishing are readily understood, especially the puzzling experience that the same agent may be used to grind or polish, and that under those circumstances polishing needs a lower working pressure while at the same time a noticeably higher amount of abrasion work is consumed.

Acid-Base Relationships in High Temperature Systems. *By L. F. Audrieth, University of Illinois, Urbana, Ill.*

Concepts which define acid-base relationships in solvent media at ordinary temperatures may be extended to high temperature systems to explain phenomena which characterize many of the important reactions in metallurgy, ceramics, and glass technology. The protonic concept accounts for the behavior of "onium" salts (cationic acids) and so-called acid salts (anionic acids) as fluxing agents. The generalized electronic theory (which defines bases as electron pair donors and acids as electron pair acceptors and neutralization as the formation of a covalent bond) can be applied to high temperature nonprotonic systems. The Lux-Flood proposal is more specific in suggesting that oxide ion transfer from one state of polarization to another is characteristic of acid-base relationships in oxide systems; similar reactions involving fluorides and sulfides are also possible. However, positive ions may also possess acid character and their behavior as such is a function of size and charge. In order to maintain the essentially covalent character of matter in the glassy state, it is necessary that the modifying cation acid exert a competitive polarizing influence on oxide ions coordinated with the glass-forming element.

Polymerization and depolymerization reactions as a function of the potential acidity of reactants in high temperature systems are compared with phenomena which occur in solvents at ordinary temperatures.

The Equilibrium Density of Glass and its Relation to the Atomic Arrangement. *By R. W. Douglas, Research Laboratories, General Electric Co., Ltd., Wembley, England.*

The origins of the slow changes in the physical properties of glass in the transformation range are discussed. Particular attention is paid to the equilibrium density of glasses. The behavior of fused silica, a borosilicate glass, and a lime-soda glass is considered and several different causes of density change are suggested. These include: varying degree of disorder as in normal liquids, existence in silicate glasses of directed binding forces, and phase separation.

Structure and Properties of Crystalline and Vitreous Boron Oxide. *By Stephen W. Barber, Owens-Illinois Glass Co., Toledo, Ohio, and Kasimir Fajans, University of Michigan, Ann Arbor, Mich.*

According to current views, the structure of vitreous boron oxide consists of a continuous network of oxygen triangles held together by the cations B^{3+}. However, the properties of boron oxide cannot be understood if a consideration of the electric forces involved is applied to such a coordinative structure.

The apparent molar refraction per one O^{2-} is lower in boron oxide than in aluminum oxide, showing that the small B^{3+} exerts, on the average, stronger forces on O^{2-} than does the larger Al^{3+}. Nevertheless, the melting point of crystalline boron oxide is 450°, that of aluminum oxide is 2045°C. This apparent contradiction can be resolved if one assumes that the relatively weak forces, indicated by the low melting point of boron oxide, are due to the interactions between molecules $(B_2O_3)x$ while the strong forces are due to the intramolecular interactions between B^{3+} and O^{2-}. It will be shown that the following properties of crystalline or vitreous boron oxide at temperatures below 300°C. also support this assumption: heat capacity, surface tension, thermal expansion, and viscosity. The available X-ray data concerning the internuclear distances in vitreous boron oxide can be reconciled with these conclusions.

In the range between 300° and 1400°C. the structure of vitreous boron oxide gradually changes, with increase in temperature, from a molecular towards a coordinative one.

BALL BROTHERS NAMES MANAGER OF NEW DIVISION

The creation of a new and wholly independent Box and Paperboard Division of Ball Brothers Company Incorporated and the appointment of Burnham B. Holmes to be General Manager of the new operating group has been announced by Edmund F. Ball, President.

Mr. Holmes, a former sales executive for Inland Container Corporation until he joined the Ball company a year ago, will be responsible for all corrugated box and paperboard manufacturing, as well as the coordination and correlation of shipping container procurement with the company's own box and paperboard production.

It was announced that Mr. Holmes will be free to devote his full time to the problems involved in paper and paper box manufacturing and procurement of supplies beyond the company's capacities to produce its shipping containers and packaging requirements.

NEWARK MUSEUM OBTAINS ANCIENT GLASS COLLECTION

Dating from about 1500 B.C., the Egyptian toilet jars shown are examples of the oldest methods of glassmaking. A dragged design is laid on glass of a rich blue in glass threads of a contrasting color. The maker used a core mold held on a metal bar, and the glass was prepared in rods, softened, and wound around the mold in a manner similar to coil-wound pottery.

One of the finest and most extensive groups of ancient glass objects in the United States is included in the Eugene Schaefer Collection of classical antiquities recently presented to the Newark Museum, Newark, New Jersey, by Mr. Schaefer's widow, Mrs. Eugene Schaefer, of Englewood, New Jersey, as a memorial to her late husband.

Ranging in period and type from 18th dynasty (ca. 1600 B.C.-1370 B.C.) Egyptian jars to Merovingian (486-752 A.D.) drinking vessels, the collection includes glass objects illustrating almost every shape and technique used in antiquity. Among the types of glass are blown vessels, core-wound vases, an unusual group of mosaic placques of heads and other designs, millefiori bowls, and several polygonal glasses with impressed patterns of religious symbols, including one of the rare type with abstract heads on two of its faces. The group of mold-blown glass is highlighted by three inscribed pieces of special interest —a cup from the famous workshop of Ennion inscribed "Ennion epoiei"; an amber tumbler with the inscription "take the victory", and another with the words "entering, take the victory".

Illustrating the use of glass in ancient jewelry are many fine pieces of gold work, particularly a magnificent gold necklace with glass beads and insets.

The collection, gathered by Mr. Schaefer over a long period of years, was begun when he was a boy in Germany, and continued until his death in 1934. He acquired a number of the objects during trips to Europe and the East, and others from dealers in New York. After his death, the collection was placed on loan with the Worcester Art Museum, Worcester, Massachusetts, where it was on display until the beginning of World War II.

Most of the glass, pottery, bronze, and jewelry in the collection was put on exhibition at the Newark Museum beginning April 17, to continue on view through the year.

Museum hours are: 12 to 5:30 daily; 7 to 9:30 on Wednesday and Thursday evenings, and from 2 to 6 p.m. on Sundays and holidays.

These drinking cups, rare inscribed glass of the Roman Empire, were blown in a mold and have good-luck inscriptions in Greek. The cup on the left is a clear greenish color, and the cup on the right is amber.

Glassware of the Roman Imperial period reached a baroque stage in its design. The simple basic form was elaborated with applied decoration, the flask on the right having sixteen handles. All of the vessels are clear glass and some are decorated in contrasting colors.

THE PHYSICAL ASPECT OF GLASS-METAL SEALABILITY IN THE ELECTRONIC TUBE INDUSTRY

By GEORGES TREBUCHON AND JACQUES KIEFFER

TRANSLATED FROM VERRES ET REFRACTAIRES, JUNE 1950

By NORBERT J. KREIDL

PART II

ESTABLISHMENT OF THE OPTIMAL ANNEALING CYCLE OF THE GLASS PROPER

Definitions

In the first part of this study, a piece of glass was termed annealed if it appears isotropic in polarized light (does not modify the "sensible" hue of the industrial polariscope).

The attainment of this state at ambient temperature is conditioned by the elimination of strain by relaxation at a certain temperature called annealing temperature, then by the elimination of gradients of temperature in the interior of the piece while it is cooled through the transformation and annealing ranges. Below a certain—the "lower annealing"— temperature T_I, the temperature gradients in the inside of the piece have no longer a permanent effect and the rate of cooling must only be limited to avoid rupture by temporary strain.

If homogeneity of temperature is realizable, the maximum permitted cooling range is conditioned by: (a) Intrinsic glass variables (thermoviscous properties, coefficient of expansion, etc.), (b) Shape variables.

The optimum annealing cycle shall be defined by its elements viz.:

Annealing	(holding)	temperature	T_r
Annealing	(holding)	time	t_r
Cooling Rate			v

so that the duration of the cycle becomes a minimum.

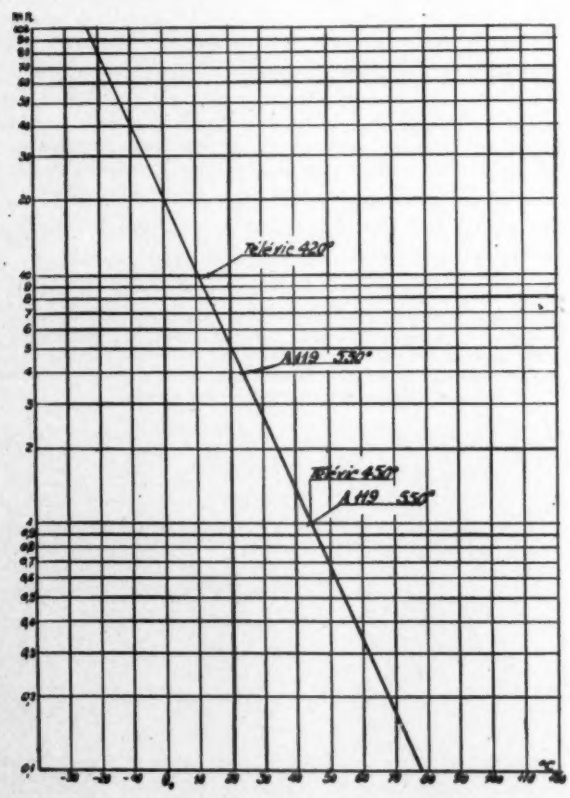


Fig. 26. Relation Between Annealing Time and Annealing Temperature of the Glass Proper. Time in minutes. Temperature in °C. starting at the annealing temperature (Televic: 406°C., A-119: 506°C., other temperatures labelled).

Theoretical Derivation of the Simplified Optimum Annealing Cycle

Starting from viscosity as a base, G. D. Redston and J. E. Stanworth[15] have effectuated the theoretical determination of this optimum cycle. The essential elements will be reviewed here.

Relation Between Annealing Temperature and Annealing Time.

From Maxwell's equation of strain relaxation, a linear relation between T_r and log t_r can be obtained for the achievement of a given decrease of strain, e.g. $p/p_o = 1/1000$ (p *final*, p_o *initial* strain.)

Fig. 26 represents this relation as a curve, θ_o being the annealing point, i.e. the temperature for a viscosity of 10^{13} poises and $t_r = 21$ minutes.

Theoretical Relation Between Expansion, Thickness, and Cooling Rate.

Fig. 27 gives Adam's-Williamson's relation of cooling rate and thickness for various expansions, said to achieve strain less than 2.5 millimicrons per cm, which is a strain not shown in an industrial instrument on glasses less than 1 cm thick.

If v is the cooling rate, e the thickness, this relation may be written:

$$\log v = A \log e + B$$

in which A is independent of the expansion, and B decreases with increasing α (it is well known that glasses of higher coefficient are more easily broken by thermal shock).

Relation Between Cooling Rate and Annealing Temperature for the Shortest Cycle of a Given Specimen.

From Fig. 26 and 27, one can establish (a) the holding time at a certain temperature to reduce the strain to 1/1000, and (b) the cooling rate for a sample of which one knows α and e.

Starting from the cooling curve at the proper linear rate (xx^1 on Fig. 28) one can draw a curve Γ so that segments like bc represent the holding times for the temperatures T_r. For every cooling curve xx^1, one can draw a curve Γ defining holding times bc.

It is easy to see that the minimum time B'D is achieved by the cycle BCD for which the segment BC

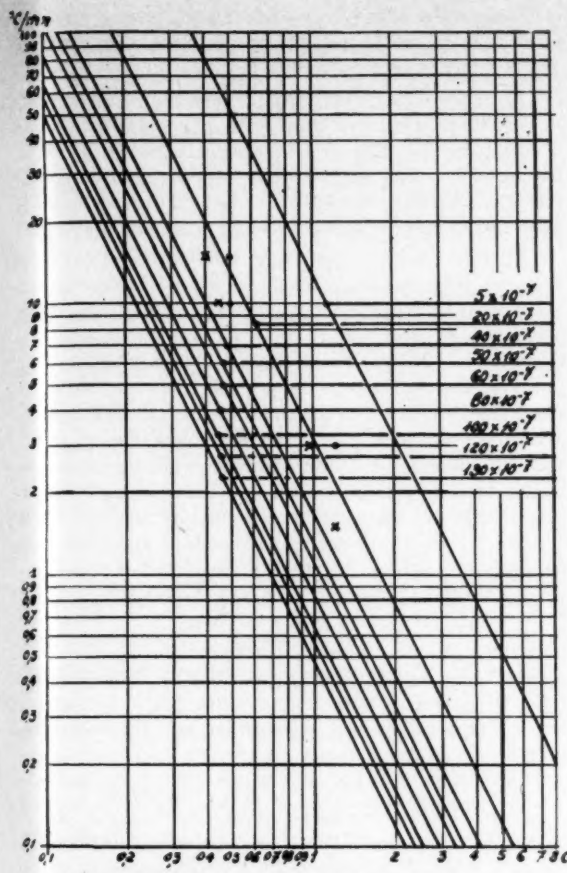


Fig. 27. Relation Between Expansion, Thickness of Glass, and Cooling Rate. Rates in °C./min. Thicknesses in cm. — x Televic: α 20-300 = 95, A-119: α (20-300) = 52.

has as an origin the point of curve Γ for which $dT_r/dt = \infty$. This optimum time is designated $t_r op$. The relation of v (cooling rate) and $T_r op$ (optimum annealing temperature) is graphically expressed in Fig. 29.

Resumé of the Determination of the Shortest Cycle.

(1) If α and e (expansion, thickness) are known, take v (cooling rate) from Fig. 27.

(2) If v is known from (1), take optimum annealing temperature $T_r op$ from Fig. 29.

(3) If $T_r op$ is known from (2), take optimum annealing time $t_r op$ from Fig. 26.

Experimental Verification of the Redston-Stanworth Theory

Series of experiments with hard (A-119) glass and molybdenum, as well as with soft (Televic) glass and ferrochrome, have been conducted on samples type B (Fig. 8, Part I, *Verre et Refr. 4* (3) 1950) without metal core and on 40 mm discs of thicknesses 1-20 mm.

The following conclusions were reached:

Relation Annealing Temperature: Holding Time.

Redston and Stanworth established their relation for $p/p_o = 1/1000$. Since in the present study p_o is small, in the present study holding times were determined for obtaining strain less than detectable in the instrument described in Fig. 18.

The experimental points were entered in Fig. 26 after

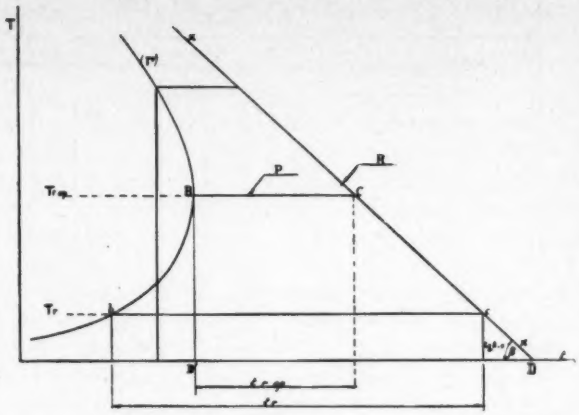


Fig. 28. Determination of Optimum Annealing Cycle For a Given Sample. P: — Hold. — R: cooling.

a suitable translation to make the holding time 21 minutes for θ_o.

Under these conditions it was found that the temperatures θ_o could be assimilated to transformation temperatures T_g' of annealed glasses with an approximation ± 5°C.

Relation Between Expansion, Thickness, and Cooling Rate.

The experimental points on Fig. 27 are to the right of the corresponding theoretical curves (curve 95.10^{-7} for Televic (x), curve 52.10^{-7} for A-119). Thus the Redston-Stanworth laws offer enough security.

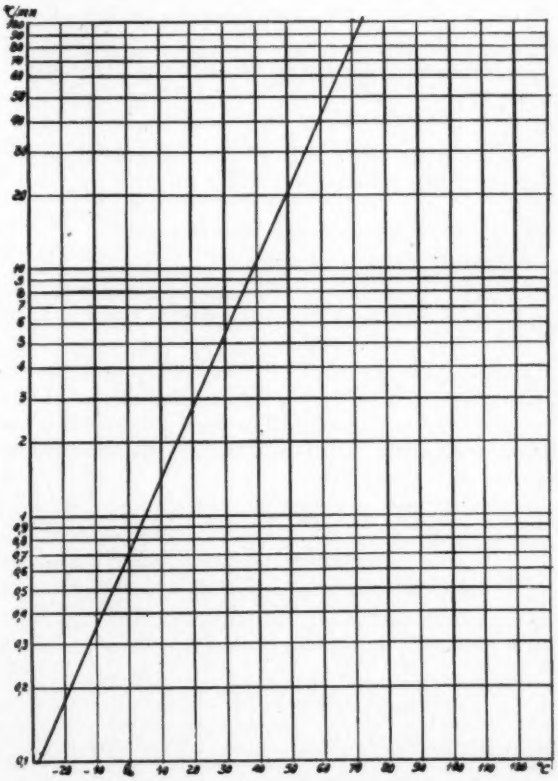


Fig. 29. Relation Between Annealing Temperature and Cooling Rate of Glass Proper.

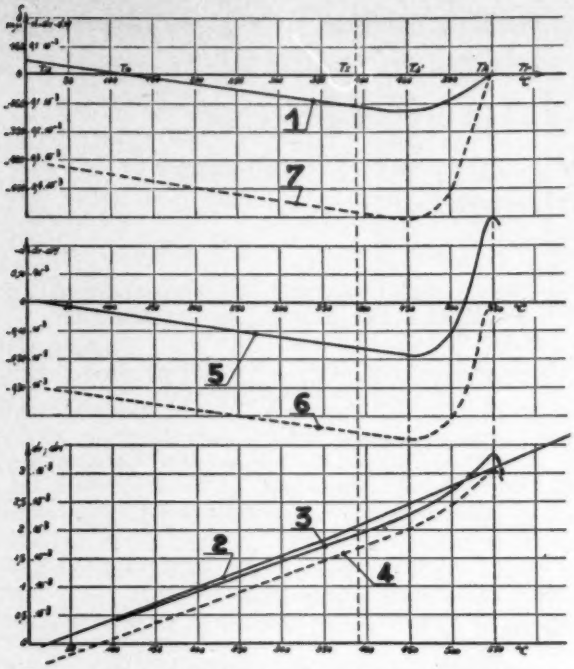


Fig. 30. Seal Molybdenum — Glass A-119. Comparison of Dilatometric and Polarimetric Curves.

Upper Ordinates: Path Difference δ Differential Contraction (— d) = d Glass — d Metal in millimicrons

Medium Ordinates: Differential Contractions (— d) = d Glass — d Metal

Lower Ordinates: dV (Glass Contractions) and dM (Metal Contractions).

Abscissae: Temperature °C. Curves (1) Polarimetric. B2, 3°/min.; (2) Dilatometric. Molybdenum; (3) Dilatometric. Glass A-119. Annealed; (4) Like 3 — Translated; (5) Differential Dilatometric. Molybdenum — Glass A-119, Annealed. 20-550°C.; (6) 5, Translated; (7) 6, Retraced at Scale $\delta/d = -BE_2 K (a - a_o)$ from T_a to T_1.

The plot Fig. 29, which is deducted from those preceding, will therefore offer the same security.

Practical Shortest Cycles For Glasses Used in the Tube Industry

In order to realize for each practical case the shortest cycle one determines (a) The acceptable cooling rate v, (b) The holding temperature T_r, (c) The holding time t_r.

Considering the diversity of glasses (T_s' from 350 to 550°C., α from 40 to 110 $\times$ 10^{-7}) and thicknesses (.5 to 10 mm) used in the construction of electronic tubes, the practical difficulties will be encountered in establishing a shortest cycle for each case.

While one will strive towards shortest cycles, one will also work towards a reasonable minimum of different cycles which was done on the following basis:

(1) The holding time was standardized to avoid practical errors. This was done with due consideration to installations available and the achievement of ± 10°C. homogeneity. The holding time also was not to constitute a major part of the cycle. In practice, 20 minutes were found suitable and this choice was maintained.

(2) Two cooling rates were standardized. (a) One rate was corresponding to the normal cooling rate of the available installations, namely 15°/min. maximum between 550° and 350°C., and 10°/min. maximum below 300°C. This schedule is safe for hard glasses up to 3 mm, and soft glasses up to 2 mm thickness. (b) One rate corresponding to a program set by automatic control permitting safe treatment of pieces of hard glass up to 12, and soft glass up to 10 mm thickness. The program controller may be arrested at the lower annealing temperature since from then the normal cooling rate of the installation is slow enough to safeguard against breakage by temporary strain. In practice, one selects for the program schedule 3°/min., down to 300°C. for hard, 250°C. for soft glasses.

It remains, then, only to determine the holding temperature. It has been shown that for 20 minutes holding time the transformation temperature (T_s') is suitable which therefore has been selected for annealing the glass proper.

The shortest cycle can thus be reviewed as below.

For still thicker pieces, a practical cycle can be determined from Fig. 26, 27, 29. It will chiefly affect the cooling rate, while 20 minutes at the transformation temperature T_s' will still suffice for the hold.

ANNEALING CYCLE FOR GLASS-METAL SEALS

In the preceding sections, the elements determining the shortest cycle for the glass proper were given. It remains to be examined to which extent this cycle is applicable or adaptable to the glass-metal seal. For this purpose the three groups of factors capable of acting upon the strains of the seal shall be examined:

(1) Intrinsic Material Variables.
(2) Cycle Variables.
(3) Shape Variables.

(a) In the following sections, a strain corresponding to a path difference is supposed to mean axial strain, according to Poritzky's approximation, applied to sample type B (Fig. 8, Part I.) (b) Maxima and minima will always denote algebraic maxima or minima.

	Thickness	Holding Temp. T_r	Holding Time t_r	Cooling Rate v
Hard Glasses	below 3 mm	T_s'	20 min.	normal rate (a) 15°C./min. max. from 550°C.
α 40-55.10^{-7}	above 3 mm and below 12	T_s'	20 min.	(b) 3°/min. to 300°C., then normal (a) = about 10°/min.
Soft Glasses	below 2 mm	T_s'	20 min.	normal rate (a) 15°C./min. max. from 550°C.
α 85-110.10^{-7}	above 2 mm and below 10	T_s'	20 min.	(b) 3°/min. to 250°C., then normal (a) = about 10°/min.

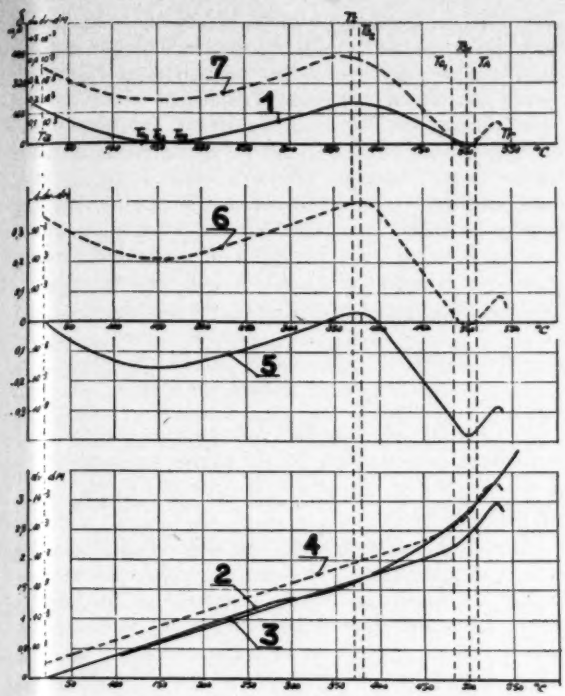


Fig. 31. Seal Dilver P — Glass L. Comparison of Dilatometric and Polarimetric Curves.

Upper Ordinates: Path Differences δ in Millimicrons. Differential Contraction (— d) = d Glass — d Metal

Medium Ordinates: Differential Contractions (— d) = d Glass — d Metal

Lower Ordinates: Contractions of Glass (dV) and Metal (dM)

Abscissae: Temperature °C. Curves (1) Polarimetric. B2 3°/min.; (2) Dilatometric. Dilver P; (3) Dilatometric. Glass L. Annealed; (4) 3, Translated; (5) Differential Dilatometric Dilver P — Glass L. Annealed 20-550°C.; (6) 5, Translated; (7) 6, Retraced at Scale $\delta/d = -BE_2 K (a - a_0)$ between T_s and T_i.

Influence of the Intrinsic Variables of Materials

The definition of these variables and their experimental determination, as well as their part in the formation of strains in the sample type B in temperature ranges where glass is considered elastic, have been treated in previous sections. It was shown that only the polarimetric test was capable of representing the strains forming at every instant during cooling and permitted to determine the room temperature strain of a sample termed annealed, i.e., one in which only strains due to the differential glass-metal contraction subsisted.

Now the detailed process in the entire cooling range, particularly, however, in the so-called transformation and annealing ranges, shall be studied. These ranges are limited by the dilatometric softening point T_R and the so-called lower annealing temperature T_I.

Dilatometric - Polarimetric Correspondence: Sealing Temperature.—Temperature of Maximum Strain.—Temperature of Zero Strain.—Relaxation Effect.—Annealing.

Metals of Constant Expansion Coefficient. Polarimetric Curve.

A sample B2 (B type of metal radius a = 2 mm.) is placed in the polarimetric furnace (Fig. 18). The temperature is carried beyond the dilatometric softening

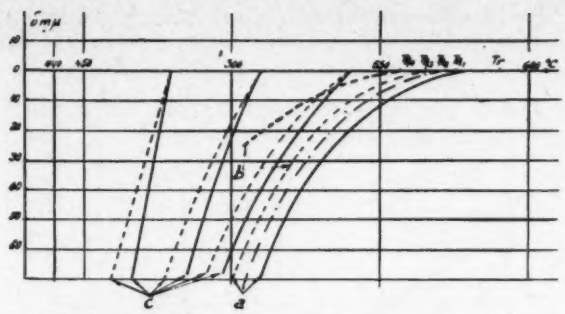


Fig. 32. Seal Molybdenum — Glass L 621. Samples B2, B 0.5 (type Fig. 8, metal radii 2, .5). Variation of the Sealing Temperature. Ordinates: Path Differences in Millimicrons. Abscissae: Temperature °C.

Curves ———— B2, 10°/min.
—— . —— . " 3°/min.
— — — — " .75°/min.
— — — B 0.5 .75°/min.

(a) Influence of Cooling Rate. (b) Influence of Shape Factors. (c) Identity of Sealing and Annealing Temperature.

point and held until all strain disappears. Then, the polarimetric curve is registered as the sample is cooled at constant rate (slow enough to avoid permanent strain to be introduced in the transformation and annealing regions, nor temporary strain in the elastic region, e.g. in the case of a B2 sample 10°/min.).

The curve 1 Fig. 30 is obtained.

From the temperature T_r at which the sample had been held until no strain was observed at T_A, no strain appears as the glass is sufficiently plastic to follow deformations imposed by the metal.

From the temperature T_A (the "sealing temperature") the glass is no longer plastic enough to follow the deformations imposed by the metal and strains appear.

The path difference—therefore the strains—pass a maximum in absolute value at T_g'—the "temperature of maximum strain" (absolute maximum), then zero at the "temperature of zero strain", and finally assumes a definite value at ambient temperature.

Note: This type of a curve is obtained if, as is usual, the mean coefficient of expansion of the glass is smaller than that of the metal. Otherwise neither the "maximum strain temperature" nor the "zero strain temperature" is observed, but for reasons to be discussed in Part III this case is impractical.

Experimental Correspondence Between Polarimetric and Dilatometric Curves. The experimental curves relating to the molybdenum-glass A-119 seal can be studied in Fig. 30.

Curve 1: Polarimetric, B2 3°/min. (See *Polarimetric curve*).

Curve 2: Absolute dilatometry of molybdenum.

Curve 3: Absolute dilatometry of glass A-119.

Curve 4: Curve 3 translated along the dilatation axis until it cuts the molybdenum dilatation curve at T_A.

Curve 5: Differential dilatometry (directly, or from 2 and 3).

Curve 6: Curve 5 translated along the difference of dilatation axis until it cuts the temperature axis at T_A.

Curve 7: Scale conversion of 6 to make it parallel to curve 1 in the elastic range. (Use is made of the relation $\delta = -BE_2 dK\ (a—a_o)$.)

Besides the inferences regarding the elastic range (below T_I), the following conclusions can be drawn from the observation of these curves: (a) Maximum path difference and therefore maximum strain are observed near the temperature of maximum (absolute value) differential dilatation. This is also where α Glass $= \alpha$ Metal. (b) The maximum strain,—absolute value —, is not equal to that given by the relation established for the elastic range and then applied to T_A to T_S': it is much smaller. (c) The zero strain temperature does not correspond to the temperature of zero differential strain; it is much higher. (d) The value of the path difference at ambient temperature (and therefore the strain at ambient temperature) does not verify the relation:

$$[\delta]\ {}^{Ta}_{T_A} = -BE_2\ [d]\ {}^{Ta}_{T_A}\ K\ (a—a_o)$$

It is even of opposite sign.

Summarizing, the complete polarimetric curve cannot be deduced quantitatively by the simple proportionality of the differential contraction starting at T_A (the "sealing temperature").

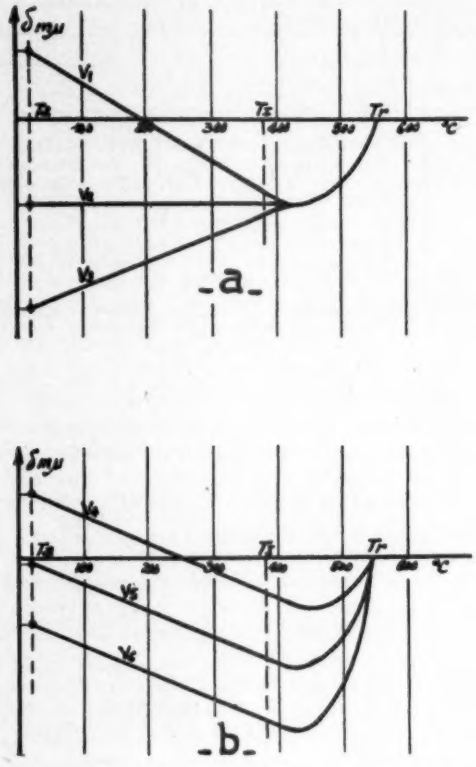


Fig. 33. Glass-Metal Seal for Constant Expansivity of the Metal. Glass A-119 — Molybdenum. — Sample Type B2. Influence of the Dilatometric Curve of Glass on the Polarimetric Curve. For the purpose of simplification, the annealing temperatures and the coefficients B and E_2 are assumed identical for all glasses.

Glass 1 (V1) Glass 2 (V2) Glass 3 (V3)

a: $\alpha\ {}^{Tr}_{TS'}$ **Metal** $< \alpha\ {}^{Tr}_{TS'}$ **Glass 1** $= \alpha\ {}^{Tr}_{TS'}$ **Glass 2** $= \alpha\ {}^{Tr}_{TS'}$ **Glass 3**

$\alpha\ {}^{TI}_{Ta}$ **Metal** $= \alpha\ {}^{TI}_{Ta}$ **Glass 2**

$\alpha\ {}^{TI}_{Ta}$ **Glass 1** $< \alpha\ {}^{TI}_{Ta}$ **Glass 2** $< \alpha\ {}^{TI}_{Ta}$ **Glass 3**

Glass 4 (V4) Glass 5 (V5) Glass 6 (V6)

b: $\alpha\ {}^{Tr}_{TS'}$ **Metal** $< \alpha\ {}^{Tr}_{TS'}$ **Glass 4** $< \alpha\ {}^{Tr}_{TS'}$ **Glass 5** $< \alpha\ {}^{Tr}_{TS'}$ **Glass 6**

$\alpha\ {}^{TI}_{Ta}$ **Metal** $> \alpha\ {}^{TI}_{Ta}$ **Glass 4** $= \alpha\ {}^{TI}_{Ta}$ **Glass 5** $= \alpha\ {}^{TI}_{Ta}$ **Glass 6**

$\left\{{}^{Tr}_{TS'}\right.$ **. . . coefficients in the upper range (annealing range).**

$\left\{{}^{TI}_{Ta}\right.$ **— . . coefficients in the lower range (from transformation (T_I) to ambient (T_A) temperatures. Note by Translator.)**

(In other words: (a) The high range expansivities of three glasses are equal and higher than the metal. The low range expansivity of the metal equals the No. 2 glass, No. 1 being lower, No. 3 higher.

(b) The high range expansivity of the metal is smaller than of glass 4, 5, 6 in increasing order. The low range expansivity of the metal is greater than the equal ones of all three glasses 4, 5, 6. Note by Translator.)

From the practical viewpoint only the following elementary phenomena should be considered:

In the entire transformation and annealing range—practically from T_R to T_I—at all temperatures, the variation of strain—and, therefore, that of path difference —from T to T-dT results: (a) From a variation due to the differential contraction of glass and metal (increase or decrease in absolute value depending on whether the expansivity of the metal is smaller or larger than that of glass. (b) From a variation due to relaxation (decrease in absolute value), the rate of which at this temperature is proportional to a power of the existing strain.

This double elementary phenomenon is integrated from the sealing temperature T_A to the lower annealing temperature T_I. Therefore, at T_I the measured path difference is smaller in absolute value than indicated in the relation

$$[\delta]\ {}^{TI}_{TA} = -BE_2\ [d]\ {}^{TI}_{TA}\ K\ (a—a_o)$$

However, below T_I the relation between path difference and contraction is completely ruled by the laws of photoelasticity:

$$[\delta]\ {}^{T}_{TI} = -BE_2\ [d]\ {}^{T}_{TI}\ K\ (a—a_o)$$

The existence of the relaxation phenomenon therefore suffices to explain all previously described results,

Theoretical Interpretation: The Relaxation Phenomenon. The preceding results can be explained by completing the hypothesis of the deduction of the polarimetric from the dilatometric curves, as proposed by certain authors[2, 10, 16] by the relaxation theory.

It is known that above the lower annealing temperature T_I, all strain is capable of relaxation, i.e., attenuation due to partial plasticity. The relaxation laws have been studied by various authors[17, 18]. An equation (9) would not serve the practical problem of glass-metal seal for various reasons. First, the laws of relaxation are diverse; then, in the critical range B and E_2 Brewster coefficient (B) and module (E_2) vary and are insufficiently known. Finally, the very measurement of differential contraction is subject to errors due to relaxation produced by the instrument itself.

namely: (1) The small difference between the temperature of maximum path difference (maximum strain) and that of maximum differential contraction (absolute value), (i.e. $d\,\delta/dT = O$ does not necessarily take place at α Glass $= \alpha$ Metal). (2) The displacement of the zero strain point: it is higher than the point of zero differential contraction. (3) The ambient temperature strain so different from that obtained by the brutal application of the laws of elasticity to the curve of differential contraction.

Metals of Variable Expansion Coefficient. Habitually, seals of metals of variable slope expansivity are considered realizable only with glasses having a transformation point in the lower vicinity of that of the metal. In practice the present authors were able to use glasses having transformation points equal to or even higher than that of the metal. Specifically, this was the case in the Dilver P seal.

Polarimetric Curve. Curve I of Fig. 31 is the polarimetric curve of a practical example. It lends itself to the same definitions and remarks as that referring to a metal of constant expansivity. (a) The existence of a sealing temperature T_A. (b) The existence of a temperature of minimum path difference T_{S1} and of maximum path difference T_{S2} within the transformation range (these temperatures corresponding to maximum absolute strain). (c) The existence of a zero strain temperature T_{O1} in the transformation range. (d) The existence of a minimum strain temperature (T_{S3}) below the lower annealing temperature T_I (in the specific case not much above zero). (e) The existence of two zero strain temperatures (T_{O2}—T_{O3}) below T_I (in the specific case nearly confused).

Experimental Correspondence Between Polarimetric and Dilatometric Curves. Fig. 31 gives the experimental curves referring to the Dilver P-Glass L seal, defined as in the case of the Molybdenum-Glass A-119 seal. (See Fig. 30.) These curves invite identical remarks.

Theoretical Interpretation. Phenomenon of Relaxation. The same remarks apply as in the case of the Molybdenum-Glass A-119 seal (See *Theoretical Interpretation*).

It should be noted, however, that in the Molybdenum-Glass A-119 seal, the relaxation is revealed by a displacement of axial strains at ambient temperatures toward compression while in the Dilver P-Glass L seal, it is revealed by a displacement toward tension.

Variation of the Sealing Temperature T_A. Influence of the Cooling Rate. Because of the relaxation phenomenon, a very slow cooling rate approaching O°/min. at which the strain due to differential contraction is more thoroughly destroyed by relaxation would first result in strain at much lower temperatures than a faster cooling rate, i.e., the sealing temperature T_A is displaced towards the lower annealing temperature T_I. Conversely, if it were possible to cool at infinitely fast rate relaxation would be suppressed and T_A would fuse with the starting temperature. In this case the polarimetric curve could be deduced from the photoelastic laws alone.

Thus the mere variation of the cooling rate permits, theoretically, the variation of the sealing temperature all through the transformation range.

In practice, considering samples of the B2 type (samples of the shape shown in Fig. 8, of metal radius 2) and cooling rates from 314°C. to 10°C/min., T_A can

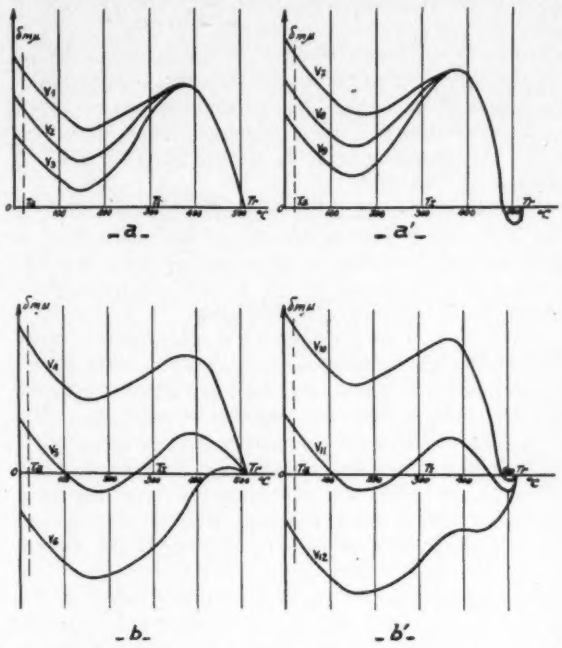


Fig. 34. Glass-Metal Seal for Variable Expansivity of the Metal.

(Glass L — Dilver P.) Sample Type B2. Influence of the Dilatometric Curve of Glass on the Polarimetric Curve. For the purpose of simplification annealing temperatures and coefficients B and E_2 are taken equal for all glasses.

Glasses No. 1, 2 etc. marked V1, V2 etc. on curves.

(a) $\alpha^{Tr}_{TS'}$ Glass 1 $= \alpha^{Tr}_{TS'}$ Glass 2 $= \alpha^{Tr}_{TS'}$ Glass 3 $< \alpha^{Tr}_{TS'}$ Metal

α^{TI}_{Ta} Glass 1 $< \alpha^{TI}_{Ta}$ Glass 2 $< \alpha^{TI}_{Ta}$ Glass 3 $= \alpha^{TI}_{Ta}$ Glass 2 $= \alpha^{TI}_{Ta}$ Metal

(In other words: The high range expansivities of three glasses are equal to each other and smaller than of the metal. The low range expansivities of the three glasses increase from 1 to 3, 2 being equal to that of the metal. Translator's Note.)

(b) $\alpha^{Tr}_{TS'}$ Glass 4 $< \alpha^{Tr}_{TS'}$ Glass 5 $< \alpha^{Tr}_{TS'}$ Glass 6 $< \alpha^{Tr}_{TS'}$ Metal

α^{TI}_{Ta} Glass 4 $= \alpha^{TI}_{Ta}$ Glass 5 $= \alpha^{TI}_{Ta}$ Glass 6 $< \alpha^{TI}_{Ta}$ Metal

(In other words: The high range expansivities of three glasses increase in order 4 to 6 and are smaller than that of the metal. The low range expansivities of the glasses are equal to each other and smaller than that of the metal. Translator's Note.)

(a') $\alpha^{Tr}_{TS'}$ Metal $< \alpha^{Tr}_{TS'}$ Glass 7 $= \alpha^{Tr}_{TS'}$ Glass 8 $= \alpha^{Tr}_{TS'}$ Glass 9 $= \alpha^{Tr}_{Ta}$ Metal $= \alpha$ Ta Glass 8

α^{TI}_{Ta} Glass 7 $= \alpha^{TI}_{Ta}$ Glass 8 $< \alpha^{TI}_{Ta}$ Glass 9

(In other words: The high range expansivities of the glass are equal, but greater than that of the metal. The low range expansivities of the glasses increase from 7 to 9, 8 being equal to the metal. Translator's Note.)

(b') α^{TI}_{Ta} Metal $> \alpha^{TI}_{Ta}$ Glass 10 $= \alpha^{TI}_{Ta}$ Glass 11 $= \alpha^{TI}_{Ta}$ Glass 12

$\alpha^{Tr}_{TS'}$ Metal $< \alpha^{Tr}_{TS'}$ Glass 10 $< \alpha^{Tr}_{TS'}$ Glass 11 $< \alpha^{Tr}_{TS'}$ Glass 12

(In other words: The high range expansivities of the glasses increase from No. 10 to 12, and are larger than that of the metal. The low range expansivities of the glasses are equal and smaller than that of the metal. Translator's Note.)

not be displaced beyond a narrow limit near the dilatometric softening point T_R.

Fig. 32a shows the displacement of the sealing point T_A for the Molybdenum-Glass L seal, sample type B (Fig. 8), radius 2.

Influence of Sealing Factors. At equal relaxation the sealing point will be higher if differential contraction of the shape of the sample brings about a greater elastic variation of the strain. Fig. 32b shows this variation for a seal Molybdenum-Glass L, cooled at .75°C/min. in samples type B2, B0.5.

Identity of Sealing and Annealing Temperature. It has been shown that given the quality and shape of glass as normally used in the electronic tube industry, cooling rates of several (3-15)°C/min. can be used depending upon the thickness of the glass.

Under such cooling conditions it was found in many experiments that in seals involving hard as well as soft glasses, metals of constant as well as variable expansivity, and starting from temperatures of annealing (T_r) in the interval between the lower annealing temperature T_I and the dilatometric softening point T_R (both determined in the differential dilatometer with a load of 8 g/mm² on rods of φ3mm diameter, at a rate of 3°/min.):

The sealing temperature is confused with the annealing temperature.

This result may be explained by the fact that the practical annealing temperature corresponds to a lesser viscosity than the sealing temperature. (Experiments with the Molybdenum-Glass L seal. Fig. 32c.)

Definition of a Practical Optimum Annealing Temperature of Glass-Metal Seals. During this study the following statements could be made: (1) All annealing temperatures below T_S (upper annealing temperature of glass) lead to long holding times (longer than 1½ hours), (2) All annealing temperatures near T_R (dilatometric softening point) provoke deformation.

It remained to determine the practical optimum temperature in this interval. It appeared interesting to maintain the holding temperature of 20 min. which had been selected in the determination of the optimum schedule for the glass alone.

A large number of experiments showed that the optimum annealing temperature could be taken at $T_S + \frac{1}{3}(T_R - T_S)$, i.e., above the upper annealing temperature of glass, one third between that temperature and the dilatometric softening points.

Before the definite establishment of the optimum annealing cycle of glass-metal seals, it remains to examine the variation of strain as a function of various factors.

Influence of the Shape of the Dilatometric Curve of Glass on the Strain.

Concerning the influence of the shape of the dilatometric curve one has to consider: (a) The expansion coefficient from T_a to T_I which is essentially constant, (b) The expansion coefficient above T_S' (from T_S' to T_R), (c) The value of T_S'.

One knows that there are glasses of weak "structural effect", i.e., glasses the expansivity of which is not as much decreased below T_I; and glasses of strong "structural effect", i.e., glasses with a great difference $\alpha \frac{TR}{TS'} - \alpha \frac{TI}{Ta}$.

Influence of the Coefficient From T_a to T_I (Ambient to Transformation Temperature). In Fig. 33a, 34a, a′ is

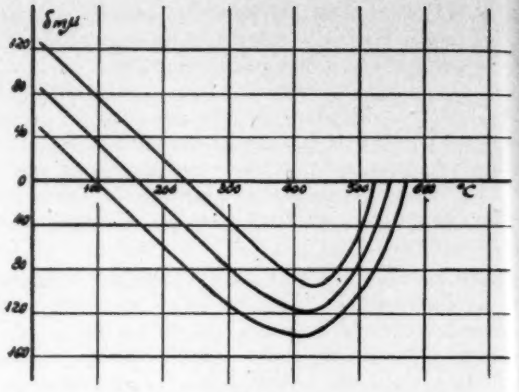


Fig. 35.

represented a scheme of the influence of this coefficient on the strains for metals of constant (Molybdenum) and variable expansivity (Dilver P). The curves were taken on B2 type samples. (B see Fig. 18. 2 refers to a metal radius of 2 in a total 7.5 of this type.) In the interior the glasses are not supposed to differ but by the coefficient $\alpha \frac{TI}{Ta}$.

In the elasticity domain, the figures cannot express anything but the established relations.

(a) From temperatures T_1 to T_2:

$$[\delta]\frac{T_2}{T_1} = -BE_2\,K\,(a - a_o)\,d$$

$$= -BE_2\,K\left[\left(\alpha\frac{T_2}{T_1}\text{Metal} - \alpha\frac{T_2}{T_1}\text{Glass}\right)\right](T_2 - T_1)$$

On heating:

$$[\delta]\frac{T_2}{T_1} < O \text{ if } \alpha\frac{T_2}{T_1}\text{Metal} > \alpha\frac{T_2}{T_1}\text{Glass}$$
$$> O \text{ “ “ } < \alpha \text{ “}$$

On cooling:

$$[\delta]\frac{T_2}{T_1} < O \text{ if } \alpha\frac{T_2}{T_1}\text{Metal} < \alpha\frac{T_2}{T_1}\text{Glass}$$
$$> O \text{ “ “ } > \alpha \text{ “}$$

In both cases:

$$[\delta]\frac{T_2}{T_1} = O \text{ if } \alpha\frac{T_2}{T_1}\text{Metal} = \alpha\frac{T_2}{T_1}\text{Glass}$$

(b) At the temperature T

$$d\delta/dT = -BE_2\,K\,(a - a_o)\,(\alpha\,\text{Metal} - \alpha\,\text{Glass})$$

and

$$d\delta/dT > O \text{ if } \alpha\,\text{Metal} < \alpha\,\text{Glass}$$
$$\text{“ } < O \text{ “ “ “ } > \text{ “}$$
$$\text{“ } = O \text{ “ “ “ } = \text{ “}$$

Note on the figures the formation of strains at room temperature depending on Glass (Shift towards tension of the polarimetric curve as Glass increases).

Influence of the Expansion Coefficient above T_S'. In Fig. 33b, 34b, b′ is given a scheme of this influence on the strains, for metals of constant (33) (Molybdenum) and variation (34) (Dilver P.) coefficient. The curves are taken on samples type B2. In the interior of each case the glasses are supposed to differ only by the coefficient $\alpha \frac{Tr}{T_S'}$.

This study has shown that above T_S' the photoelastic relations do not apply quantitatively but that they are capable to give the general trend.

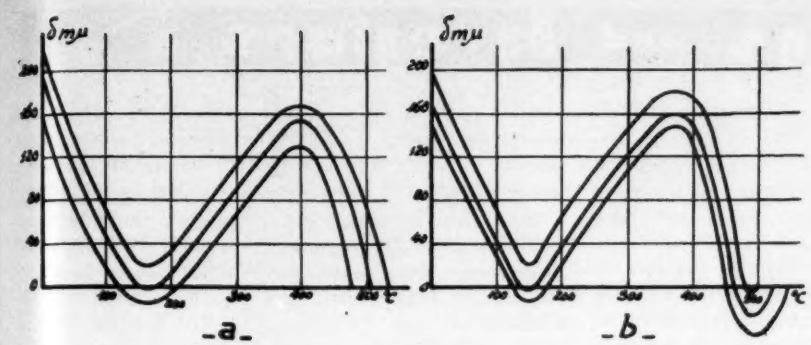


Fig. 36. Seal Dilver P—Sample B2.—Influence of Temperature on Strain. (a) Glass of weak "structural effect"; (b) Glass of strong "structural effect."

The figures show how glasses of marked structural effect may be harmful. The polarimetric curves are displaced toward tension as $\alpha \frac{Tr}{TS'}$ increases.

Note the variations in shape of polarimetric curve on metals of variable coefficient when the difference $\alpha \frac{Tr}{TS'}$ glass — $\alpha \frac{T}{TS'}$ metal changes sign.

Influence of the Transformation Point. The number of hypotheses required to schematize this influence is too great and the corresponding experimental conditions could not be realized. A theoretical study allows to deduce that the result of such a variation is essentially a function of the simultaneous variation of sealing and lower annealing temperatures T_A and T_g'. These results were not tested experimentally and are not described here.

Remarks. Some results of the preceding paragraphs can be presented as follows:

(a) Contrary to a frequent opinion it is not enough to find a metal-glass pair of matching expansion between 20 and 300°C. to obtain a strain free seal applicable to the construction of electronic tubes. Only if the expansion curves would coincide in the entire domain T_a to T_r (ambient to upper annealing temperature) could one realize a strain free seal at all temperatures.

(b) In all seals involving a metal of variable expansivity, such as Dilver P, one can step from one to another prototype of polarimetric curve only by the augmentation of the "structural effect" of glass, the transition being marked by equality of the high range expansivities of glass and metal. ($\alpha \frac{Tr}{TS'}$ Glass $= \alpha \frac{Tr}{TS'}$ Metal).

Note: The experimental verification was only indirect and based on three years experience. It is obviously impractical to fabricate special glasses of the required characteristics.

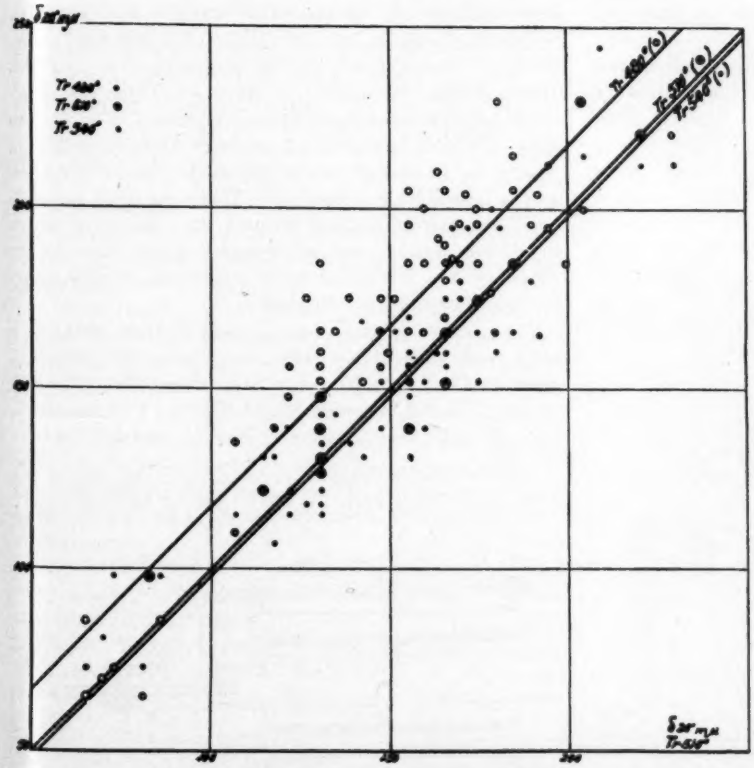


Fig. 37. Seal Dilver P — Glass L 621 Sample B2. Influence of Annealing Temperature on Room Temperature Strain. Statistics of 90 good shipments of Dilver P.

Influence of the Factors of the Annealing Cycle On Strains

Influence of the Annealing Temperature On Strains.

Metals of Constant Expansivity, Figure 35 represents the exeprimental result obtained with a B2 Molybdenum A-119 Glass Seal, using annealing cycle of variable annealing temperature, with holding times equal to the respective relaxation times and constant cooling rates of 3°C/min.

The conclusions are given only in as much as they are conducive to practical application. (1) The maximum path difference (maximum strain) decreases in absolute value with the annealing temperature. (2) The zero strain temperature increases with decreasing annealing temperature. (3) The ambient temperature strain increases in algebraic value with decreasing annealing temperature, and, in some glasses, one can provoke the

(*Continued on page* 254)

Inventions and Inventors

Electric Melting Furnace. Fig. 1. Patent No. 2,545,619. Filed Aug. 5, 1947. Issued Mar. 20, 1951. Two sheets of drawings. Assigned to Societe Anonyme des Manufactures des Glaces et Products Chimiques de Saint-Gobain, Chauny & Cirey, Paris, France, by Roger E. Lambert of Paris.

This invention relates to electric melting furnaces in which carbon or graphite electrodes are in contact with the molten glass which has often caused discoloration of the glass. This invention aims to reduce or prevent such discoloration.

In the drawing there is shown a tank 10 having two electrodes 11 and 12 in the melting end and two electrodes 13 and 14 in the fining end. During normal operation these are all submerged. The electrodes are connected to a source of three phase current as shown in the diagram. Direct current comes from a generator 26 and passes through choke coils 30, 32, and 34 and to the electrodes 11, 12, and 14. Cathodes 35 and 36 are water-cooled and connected to the return side of the generator 26. This arrangement is said to greatly reduce or prevent the discoloration of the glass by the electrodes.

The patent contains three claims and ten references were cited.

Tube and Cane Machines

Method of Forming Tubing. Fig. 2. Patent No. 2,545,728. Filed Feb. 27, 1946. Issued Mar. 20, 1951. Two sheets of drawings. This is the invention of Samuel J. Everett of Thornton Heath, England.

This method is for accurately sizing the inside of tubing previously formed. The tubing may be cylindrical or of other cross-section and it may be tapered if desired. A tube 1 has the left end sealed at 2 and is positioned over a mandrel 3 placed inside a pressure casing 4. Compressed air is admitted to the casing, which is air-tight, through a tube 9 while vacuum is connected to the inside of the tube by a pipe 10. As the casing 4 is moved to the right, the tube is heated by an electric furnace 11. Oil, preferably as used in vacuum pumps, is introduced inside the glass tube to prevent it from sticking to the mandrel.

After cooling, the tube may be easily removed from the mandrel owing to the greater shrinkage of the metal mandrel. In this way a glass tube having an excellent inside surface and exact dimensions may be produced.

The patent contains eight claims and the references cited were 1,301,714, Keuppers, Apr. 22, 1919; 1,583,464, Housekeeper, May 4, 1926; 2,084,811, Keen, June 22, 1937; 2,286,401, Everett, June 16, 1942; 2,373,816, De Roche et al., Apr. 17, 1945; 2,393,970, Everett, Feb. 5, 1946; and 2,426,341, Canfield, Aug. 26, 1947.

Machine for Making Tubing. Patent No. 2,545,729. This patent was divided from the foregoing patent, the division being filed Sept. 19, 1947. The drawings are identical with those of the above patent and, of course, the inventor is the same. The issue date is also the same.

The two claims of the patent are directed to the apparatus shown in the method patent and the references cited were 2,023,665, Clayton, Jan. 24, 1934; 2,249,004, Kahn et al., July 15, 1941; 2,393,979, Everett, Nov. 22, 1941; 2,320,564, Brooks, June 1, 1943; and 547,880, Great Britain, Nov. 18, 1941.

Miscellaneous Processes

Method of Making Lamp Stems. Fig. 3. Patent No. 2,545,873. Filed Aug. 6, 1947. Issued Mar. 20, 1951. One sheet of drawings. Assigned to General Electric Company by R. L. Breadner and C. H. Simms, both residents of England. This patent will expire Apr. 10, 1965.

The figure shows the invention as used in the manufacture of stem tube units for luminescent electric discharge lamps. A die-block 1 having two holes 3 to receive wires 4 which have been pre-glassed as at 4'. An opening 8 is connected to a source of vacuum. The flanged tube 6 is positioned in the die-block around the wires and is heated by gas flames 11. When the glass has softened, vacuum is applied through the opening 8 which draws the glass so that it conforms to the shape of the die-block and into close contact with the wires 4. Two forms of the invention are shown.

The patent contains four claims and the references cited were 544,248, Cutler, Aug. 6, 1895; 872,530, Meeker, Dec. 3, 1907; 1,266,614, Newcomb, May 21, 1918; 1,395,963, Kuppers Nov. 1, 1921; 2,190,788, Horn, Feb. 20, 1940; and 2,318,652, Wiener, May 11, 1943.

Sealing Lead-in Conductors for Lamps, Etc. Patent No. 2,545,877. Filed July 15, 1947. Issued Mar. 20, 1951.

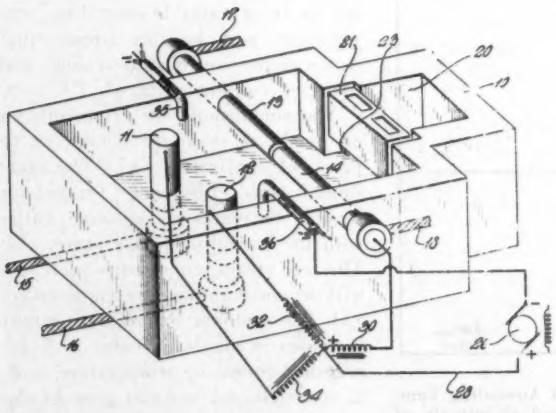


Fig. 1. Electric Melting Furnace.

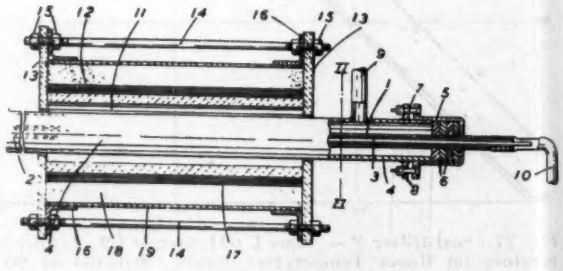


Fig. 2. Method of Forming Tubing.

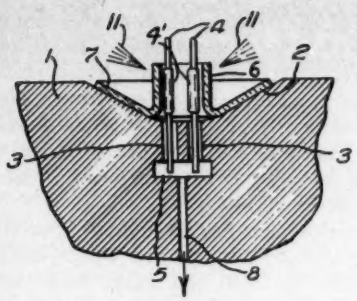


Fig. 3. Method of Making Lamp Stems.

One sheet of drawings, none reproduced. Assigned to General Electric Company by Maurice Descarsin of Paris, France.

This invention provides a method of sealing-in the conductors as used in incandescent lamps, discharge tubes, and radio tubes. The lead-in is clamped between the jaws of two cooled metal heads accurately spaced apart and adapted to be turned about a common axis. The apparatus is enclosed in a housing containing a neutral or inert atmosphere. Current is then passed through the lead-in to heat it to its oxidizing temperature. The oxidization occurs in open air.

Then the glass tube to be used as a sheath is slipped over the oxidized portion of the lead-in and the apparatus is placed under a bell in which there is a neutral atmosphere. The assembly is then heated to melt the glass and rotated at the same time.

The patent contains three claims and the references cited were 966,784, Anderson, Aug. 9, 1910; 1,280,825, Pacz, Oct. 8, 1918; 1,500,789, Aoyagi, July 8, 1924; 1,647,296, Jefferies, Nov. 1, 1927; 1,993,400, Convers, Mar. 5, 1935; 2,037,853, Danner, Apr. 21, 1936; 2,279,168, Kalischer et al., Apr. 7, 1942; and 549,277, Great Britain, Nov. 13, 1942.

Stacker. Fig. 4. Patent No. 2,547,791. Filed Apr. 4, 1947. Issued Apr. 3, 1951. Five sheets of drawings. Assigned to Anchor Hocking Glass Corporation by Opal Smith and Oral C. Dudley.

A push bar 5 is arranged to push the ware from the cross conveyor 31 onto the lehr belt 8. The push bar is carried by links 50 pivotally mounted on carriers 55 and the links are held against stops 56 by springs 62. The motion of the push bar to advance the ware onto the lehr belt, retract slightly, and then lift over the oncoming ware on the cross conveyor, is derived from a motor 85 and mechanism including a cam 92. Various speed regulating devices are provided, together with other necessary adjustments.

The patent contains 11 claims and the references cited were 1,427,164, Niver, Aug. 29, 1922; 1,662,271, Johnson, Mar. 13, 1928; 1,869,767, Nagle et al. Aug. 2, 1932; 2,077,830, Failinger, Apr. 20, 1937; 2,080,858, Dorman, May 18, 1937; 2,094,497, Ross, Sept. 28, 1937; and 2,096,656, Stoulil, Oct. 19, 1937.

Burn-off for Finishing Tumblers, etc. Fig. 5. Patent No. 2,548,743. Filed June 19, 1947. Issued Apr. 10, 1951. Four sheets of drawings. Assigned to General Glass Equipment Co., Atlantic City, N. J., by Carl W. Schreiber.

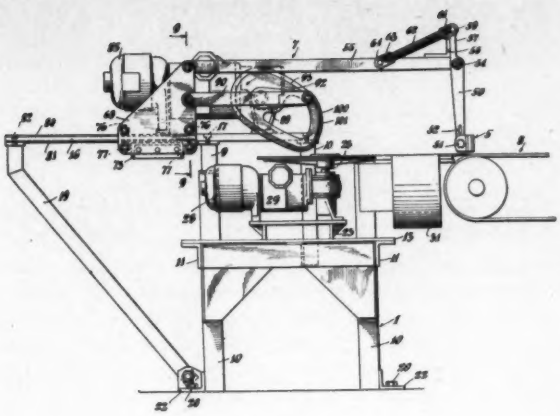


Fig. 4. Stacker.

This machine is for burning off the moil from articles, such as blown tumblers, forming a bead on the ware,

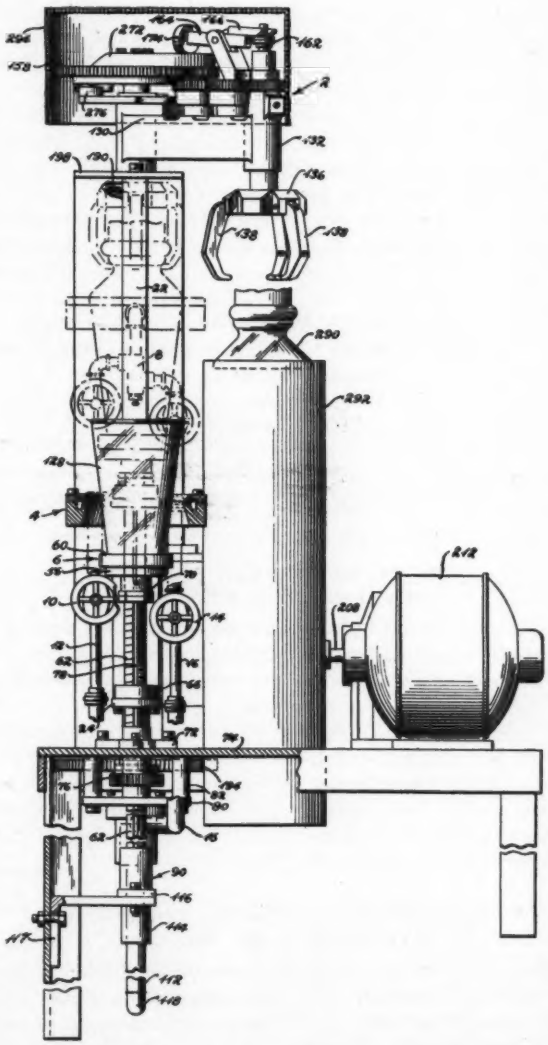


Fig. 5. Burn-off for Finishing Tumblers, etc.

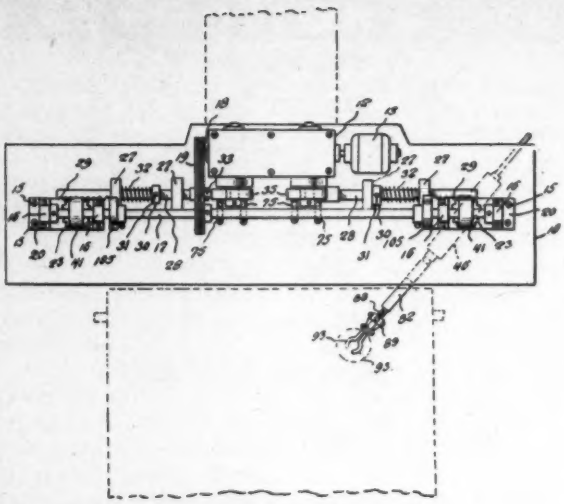


Fig. 6. Stacker.

and polishing and annealing the ware. The machine includes a chuck 2 for gripping the moil, a burner 4, and a ware holder 6. The ware 128 with attached moil is placed in the holder 6 after which the burner 4 automatically moves upward while the ware is rotated. At the same time the chuck 2 has moved into the position shown in dotted lines and the jaws closed onto the moil. Then the burner stops and the burn-off takes place while the ware is lowered to stretch the hot glass.

The burner then moves vertically to form a bead on the top of the ware and then downwardly to anneal the tumbler. The chuck 2 then swings so as to drop the moil 290 into the cullet chute 292. The finished ware is removed and another piece is placed in the holder 6.

The patent contains 10 claims and 14 references were cited.

Stacker. Fig. 6. Patent No. 2,541,574. Filed Feb. 15, 1946. Issued Feb. 13, 1951. Three sheets of drawings. Inventor Edward Crooks, Glenshaw, Pa.

This device consists of an overhead support adjacent to the end of the lehr belt with one or two vertical shafts depending from it. The lower end of the shaft carries an arm having tongs on the end to grasp the bottle. This arm swings in a horizontal plane through varying angular travel so that the bottles will be set down across the lehr belt. The tong arm also has a vertical movement. The whole operation is automatic and all necessary adjustments are provided for.

The patent contains five claims and the references cited were 315,270, Fowler, Apr. 7, 1885; 1,974,837, Shillinger et al., Sept. 25, 1934; and 2,259,728, Bridges, Oct. 21, 1941.

Preparation of Cellular Glass. Patent No. 2,544,954. Filed Mar. 31, 1945. Issued Mar. 13, 1951. No drawings. Assigned to Pittsburgh Corning Corp., by Walter D. Ford.

The material made by this process may be used for floats, insulation, and other purposes where a lightweight cellular material is required. Batches within the following ranges are recommended:

	Parts by weight
Sand	50 to 60
Soda ash	15 to 22
Lime or dolomitic limestone	12 to 20
Feldspar	9 to 16
Salt cake	3 to 8

The mixture should be fused into glass at about 2600° F. and pulverized so that 90% will pass a 350-mesh screen. 0.1 to 0.2% of carbon black is then added and the mixture is heated in a mold up to about 1600° F. which produces a block full of fine bubbles and which is nearly impervious to water.

The patent contains one claim and the following 11 references were cited: 1,108,007, Ribbe, Aug. 18, 1914; 1,945,052, Long, Jan. 30, 1934; 2,123,536, Long, July 12, 1938; 2,143,951, Lambert, Jan. 17, 1939; 2,191,658, Haux, Feb. 27, 1940; 2,233,608, Haux, Mar. 4, 1941; 2,237,032, Haux, Apr. 1, 1941; 2,255,238, Willis, Sept. 9, 1941; 2,257,681, Haux, Sept. 30, 1941; 2,272,930, Black, Feb. 10, 1942; and 2,401,582, Owen, June 4, 1946.

AMERICAN POTASH EXPANDS DEVELOPMENT PROGRAM

The announcement of an expanded research and development program designed to produce new products through improved techniques has been announced by American Potash & Chemical Corporation.

The program will be directed by Daniel S. Dinsmoor, who has been appointed Vice President in Charge of Research and Development. Mr. Dinsmoor, who joined the company in 1948, formerly was a Vice President of Monsanto Chemical Company and served as Manager of the Monsanto plant at East St. Louis.

GLASS MANUFACTURING COURSE AT UNIVERSITY OF TOLEDO

Harold R. Schutz, Chief Engineer of the Libbey Glass Division, Owens-Illinois Glass Company, is teaching a course dealing with various phases of glass manufacture at the University of Toledo.

Among the topics covered are production of glassware, batch plant layouts, furnace types, furnace construction, furnace fuels, furnace operation, forming machines, lehrs, annealing problems, selection of ware, and processing equipment.

WESTINGHOUSE NAMES MANAGER TUBE INDUSTRIAL RELATIONS

Charles H. Atkin, supervisor of industrial relations at the Westinghouse Electric Corporation plant in Fairmont, W. Va., since 1949, has been appointed Manager of Industrial Relations for the company's Electronic Tube Division.

Mr. Atkin joined the Westinghouse Lamp Division in 1942 as a member of its industrial relations department. Three years later he became supervisor of employment and training, a position he held until he went to Fairmount.

He will make his headquarters at Bloomfield, pending completion of the Electronic Tube Division headquarters near Elmira, New York.

Research Digest

Measuring Surface Durability of Glass

All glass products are subject to attack by chemical action in varying degree. There are many types of chemical attack, one of which concerns the deterioration of glass surfaces by atmospheric moisture. Attack by moisture is initially manifested by a slight dimming or iridescence over the surface, followed by the formation of a noticeable film or even a heavy white scum in varying degrees and patterns, depending on atmospheric conditions and the composition of the glass. This resistance to surface deterioration is important when one considers the unfavorable conditions of storage in unheated warehouses in northern climates or the hazards of shipping and storage in tropical climates where the humidity is excessive. The need for a laboratory method that will permit evaluation of surface durability with reasonable precision is prerequisite in developing glasses of greater surface resistance to weathering, whether by chemical composition or by surface treatment.

The principal disadvantage of the many dimming tests now used is that the results have been interpreted primarily in terms of appearance and are, therefore, subject to personal judgment. Because this interpretation varies from one individual to another, a mathematically accurate estimate is seldom possible. In the February 1951 issue of the *Bulletin of the American Ceramic Society*, H. E. Simpson describes a humidity dimming test that overcomes many of the objections of previous tests and permits a numerical grading in terms of the amount of surface dimming produced.

As described, the method of testing, in brief, provided for the exposure of properly prepared samples in an atmosphere of high humidity under a controlled two-hour temperature cycle. The alternate cycles of surface fogging and clearing consisted of a temperature drop of from 55°C. to about 50°C. and a rapid recovery to 55°C. with humidity maintained at approximately 100%. The surface deterioration so produced was measured by means of a photoelectric device known as the "haze meter" ("Tentative Method of Test for Haze of Transparent Plastics by Photoelectric Cell", A.S.T.M. Designation D672-45T, Committee D-20, pp. 1153-55, 1944). The technique, which was perfected after a study of various procedures, represents the more desirable features of a number of tests.

The possible scope of the test has not been established and further work is being planned to determine its usefulness. The important factors to be considered in the successful operation of the test follow: (1) careful cleaning and the use of filtered-air drying in order to minimize the hazard of any residue or film on the glass surface; (2) control of the cycling operation in order that alternate fogging and clearing occur on the surface of the sample; (3) adaptation of the "haze meter" to evaluate the progress of deterioration of the glass.

The various types of glasses investigated (two different compositions of window glass and four different optical glasses) show a wide variation in the type of curves produced. It is, therefore, believed that the method probably would be of value only for comparing glasses of the same type, e.g., window glasses with other window glasses, optical crowns with other optical crowns. Further, the comparisons should not be extended beyond similar types. So that a comparison might be valid, the time required for a particular glass to attain a definite amount of haze might be used as a standard. The window glasses and optical crowns attain a higher percentage of haze than some of the optical glasses and it would be necessary to establish an appropriate haze level for each type of glass.

A Study of the Effect of Lubricants on the Adherence of Molten Glass to Heated Metals

In a study of the adherence of molten glass to heated metal under conditions simulating those found in automatic glassmaking machines, Dowling, Fairbanks, and Koehler (*Journal of the American Ceramic Society*, September 1950) have improved the critical adherence temperature apparatus originally described by Kapnicky.

(*Continued on page* 262)

Table I. Suitability of Lubricants

No.	Lubricant	T_c (°F.)*	Persistence	Inflammability	Fumes	Type of deposit
1	Water base	670	N. T.†	No	Water vapor	None
2	Water base‡	885	Good	No	Water vapor	Light graphite deposit
3	Oil base	765	N. T.	Yes	Large quantities of smoke	None
4	" "	890	Excellent	Yes	" " " "	Smooth graphite deposit
5	Grease base	1050	Good	Yes	" " " "	Initial deposit causes the glass to adhere slightly; decomposes to form smooth coat
6	" "	1075	Excellent	Yes	" " " "	Rough protective graphite coating deposited
7	Silicone base	600	N. T.	Not at T_c	Unpleasant odor	None
8	" "	950	Fair	Yes	" "	None
9	" "	1100	N. T.	Yes	Products of combustion	Thick white coat; flakes easily
10	" "	1270	N. T.	Yes	" " "	Thick white coat; flakes easily
11	" "	1250	N. T.	Yes	Small quantities of smoke	Thick white coat; flakes easily
12	" "	1350	N. T.	Yes	Large quantities of sooty smoke	Thick deposit; flakes easily
13	" "	1450	N. T.	Yes	Sooty smoke	Thick deposit; flakes easily

* Values for white cast iron type "P."
† N. T.—Not tested.
‡ One part lubricant to 30 parts water.

1950 ANNUAL REPORTS

Although new records of sales and earnings were set by many glass and supplier companies during 1950, many were hit by the prolonged soda ash strike during the summer. Increased expenses and disrupted production brought about by the strike made itself felt even though production and sales were high for the first half of the year. Following is a brief review of 1950 Annual Reports which have been received from various glass companies and suppliers.

Consolidated sales and earnings of Corning Glass Works and subsidiaries for 1950 reached a new record in the company's history. Sales amounted to $116,473,981, compared with 1949 sales of $73,197,782. Net earnings after income taxes were $17,612,355, or $6.53 per share of common stock, as against $7,078,384, or $2.56 per common share in 1949.

Laclede-Christy Company's Annual Report showed net sales of $11,144,689 as compared with $8,462,316 in 1949. Net income was $807,982, or $3.74 per share, as against 1949 net income of $461,143, or $2.34 per share.

The Annual Report of Mathieson Chemical Corporation showed net sales of $75,775,756 during 1950. During 1949 net sales were $54,073,351. Net income was $8,994,014, or $3.32 per share, in 1950, compared with 1949 net income of $6,991,012, or $2.57 per share.

Thatcher Glass Manufacturing Company, Inc. reported net sales during 1950 of $18,842,272, compared with $17,787,033 during 1949. Net income for 1950 totaled $972,604, or $1.72 per share, against $924,140 for 1949, or $1.60 per share.

The 1950 Annual Report of Lynch Corporation revealed net earnings in 1950 of $1,064,392, or $2.36 per share. Shipments set a new record in 1950 with $8,519,270 as compared with $6,233,019 in 1949.

American Potash & Chemical Corporation reported net earnings of $2,559,911 for 1950, compared with $1,791,019 during 1949. Earnings on Class A and B stocks amounted to $4.34 per share for 1950, against $2.86 per share in 1949. Sales for 1950 were $17,144,550, compared with $13,692,992 for 1949.

During 1950, American Window Glass Company recorded net sales of $17,024,072, compared with $12,285,090 in 1949. Net income for 1950 was $628,136, compared with $244,203 for 1949.

New records set by Libbey-Owens-Ford Glass Company included the net sales high of $170,056,311 during 1950, compared with $134,234,001 the preceding year. Net income was $24,752,425 for the year, compared with $20,985,001 for 1949.

Net sales of Diamond Alkali Company in 1950 totaled $55,702,575, an increase of 15 per cent over the $48,430,652 reported for 1949. Net earnings were $4,829,620, or $4.45 per share compared with $3,042,298, or $2.80 per share, in 1949.

Sales and earnings for General Refractories Company, the highest in the company's history, were reported as follows: Net income was $3,518,210, equal to $7.48 per share, as compared with $1,717,509, or $3.65, in 1949. Sales were $38,198,720 in 1950, compared with $30,726,580.

Glass Fibers, Inc. showed in its 1950 Annual Report that net sales were more than triple those of 1949—$3,328,286 for 1950, $991,683 for 1949. Net profit for 1950 was $466,349, compared with a deficit of $265,356 in 1949.

The Annual Report of Anchor Hocking Glass Corporation showed net sales of $83,671,060, compared with $70,551,108 for 1949. Net income after all charges was $5,785,352, or $3.85 per share, compared with $4,404,832 for 1949, or $2.89 per share.

AVAILABILITY OF METAL FOR MOLDS

Difficulty has been experienced from N.P.A. orders, such as M-12 for copper bronze, etc., which restricts the use of this metal to 100% of the quantity used per quarter for the first six months of 1950. The situation created is similar to that experienced during World War II brought about by W.P.B. orders on iron and other metals.

The subject has been discussed with the Glass Section of N.P.A. which has conferred with appropriate sources and has received the following instructions for relief to glass manufacturers.

Form NPAF-12 should be obtained from the nearest N.P.A. branch office and filled out. This form, to be filled out in duplicate, is an appeal for readjustment of the normal allotment. The original copy should be sent, with an explanatory letter, to: Copper Division N.P.A., Attention: Mr. Coven, Main Commerce Building, Washington, D. C. The duplicate form and carbon of letter should be sent to: Mr. E. R. Killam, Chief of Ceramics Section, Consumer Goods Division, 801 E Street, Washington 25, D. C. The appeal will then be followed by the Glass Section of N.P.A. No action on any appeal for relief can be taken until the proper form has been filed with the National Production Authority.

PITTSBURGH CORNING NAMES GENERAL SALES MANAGER

H. B. Higgins, President of Pittsburgh Corning Corporation, has announced the appointment of Paul D. Japp as General Sales Manager of the firm.

Mr. Japp has been associated with Pittsburgh Corning since 1939. He was District Manager of the company's New York Branch Office until 1944 and served as General Office Sales Promotion Manager until his present assignment.

CORNING ESTABLISHES MEXICAN SUBSIDIARY

Corning Glass Works has announced the establishment of a Latin-American subsidiary, Corning Mexicana, S.A., a Mexican corporation, and the acquisition by this subsidiary of a minority interest in Cristales Mexicanos, S.A., glass manufacturers of Monterrey, Mexico. The new Corning subsidiary has offices in Mexico City, and will supervise the activities of Corning Glass Works in countries of Central America and the Caribbean area.

In the near future, Cristales Mexicanos, which now produces bottles, tableware, glass blocks, and novelties, will undertake the manufacture of such Corning products as Pyrex brand Ovenware. As in the case of its South American associated companies, the financial interest in the Mexican firm will be limited to a minority position. However, certain patents and technical knowledge and assistance of Corning Glass Works will be placed at the disposal of the management of Cristales Mexicanos.

Current Statistical Position of Glass

Employment and payrolls: Employment in the glass industry during February 1951 fell off slightly to reach 127,300 persons employed. Compared with the adjusted employment of 127,800 during January, a drop of less than 1 per cent is shown. During February 1950, employment was 108,200, or about 17½ per cent below February this year.

Payrolls for February have been reported at a preliminary $35,834,101. A drop of 2 per cent is indicated when compared with the adjusted January payrolls of $36,628,332. During February 1950, payrolls were $27,889,177, which is about 28 per cent less than for February 1951.

Glass container production, based on figures released by the Bureau of Census, jumped to 10,986,549 gross for the month of March 1951. Compared with the February production of 6,200,622 gross, an increase of close to 19½ per cent is indicated. Glass container production during March 1950 was 8,203,935 gross, which is almost 34 per cent below March this year. Total glass container production at the close of the first quarter of 1951 has reached 30,466,054 gross. During the same period in 1950, production was 23,488,003 gross, or a little more than 29½ per cent below 1951.

Shipments of glass containers during March 1951 also showed a good increase and were reported at 10,523,045 gross. Compared with the previous month's shipments of 8,771,841 gross, an increase of 20 per cent is shown for February over January. Shipments of glass containers during March 1950 were 8,312,654 gross, or 26½ per cent less than for March this year. Total shipments of glass containers at the end of the first three months of 1951 have reached 29,014,570 gross. Compared with the corresponding period in 1950 when shipments were 22,802,375 gross, 1951 shipments are running a little more than 27 per cent ahead of 1950.

Stocks on hand at the close of March 1951 are 8,090,693 gross, which is 6 per cent more than the 7,631,479 gross on hand at the end of February 1951. Stocks at the close of March 1950 were 9,453,749 gross.

Automatic tumbler production rose close to 16½ per cent during March 1951 to reach 7,570,422 dozens. February production was 6,506,152 dozens. During March 1950, production had been 6,060,658 dozens. Shipments of automatic tumblers also jumped and were reported to be 7,155,777 dozens. This is more than 16½ per cent above the 6,132,451 dozens shipped during February. Shipments during March 1950 were 6,250,865 dozens. Stocks on hand at the close of March 1951 were 10,340,140 dozens. This is 4 per cent more than the 9,939,675 dozens on hand at the close of February. Stocks at the end of March 1950 were 9,642,489 dozens.

Table, kitchen, and household glassware: Manufacturers' sales of machine-made table, kitchen, and household glassware during March 1951 jumped almost 19 per cent to reach 3,998,495 dozens, as compared with the 3,364,357 dozens sold during February 1951. Sales during March 1950 had been 3,900,264 dozens. Total manufacturers' sales during the 12-month period ending March 1951 were 40,739,232 dozens. Compared with the 39,292,019 dozens sold during the corresponding period in 1950, sales during this period are a little more than 3½ per cent above 1950.

GLASS CONTAINER SHIPMENTS

(All figures in Gross)

Narrow Neck Containers	March 1951
Foods	1,115,827
Medicinal & Health Supplies	1,530,564
Chemicals, Household & Industrial	758,250
Beverages, Returnable	430,337
Beverages, Non-returnable	16,587
Beer, Returnable	451,153
Beer, Non-returnable	526,364
Liquors	1,000,388
Wines	301,115
Toiletries & Cosmetics	645,030
Sub-total (Narrow)	6,775,615
Wide Mouth Containers	
Foods	2,324,520
Dairy Products	313,313
Home Canning	*
Medicinal & Health Supplies	403,726
Chemicals, Household & Industrial	124,731
Toiletries & Cosmetics	160,600
Packers' Tumblers	147,591
Sub-total (Wide)	3,474,481
Total Domestic	10,250,096
Export Shipments	272,949
TOTAL SHIPMENTS	10,523,045

* This figure included with Wide Mouth, Foods.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in Gross)

		Production March 1951	Stocks March 1951
Foods; Medicinal & Health Supplies; Chemicals, Household & Industrial; Toiletries and Cosmetics	Narrow Neck	4,207,739	2,980,619
	Wide Mouth	2,311,911	2,916,847
Dairy Products		325,716	303,805
Home Canning		*	*
Beverages, Returnable		517,711	547,224
Beverages, Non-returnable			19,108
Beer, Returnable		459,040	176,534
Beer, Non-returnable		500,590	151,433
Liquors		1,221,758	618,283
Wines		292,139	268,570
Packers' Tumblers		149,945	108,270
TOTAL		10,986,549	8,090,693

* This figure included Wide Mouth, Foods.

DUTCH PLATE GLASS PRODUCERS NAME U. S. REPRESENTATIVE

Dutch plate glass manufacturers recently named Philip Walmsley, an importer in International Trade Mart, New Orleans, as representative for their broad lines of plate and antique glasses.

The appointment marks the first large scale appearance of foreign-made plate glasses on the Southern market. The new lines include both glazing and mirror qualities, as well as antique types. The latter group is being produced in a broad range of colors.

(*Continued from page* 247)

change from compression to tension by an increase in annealing temperature.

To summarize: A decrease in annealing temperature is revealed by a translation of the polarimetric curve towards compression. This translation is slightly altered in the transformation zone.

Metals of Variable Expansivity. Figures 36a and b represent experimental results obtained with a sample B2 (alloy Dilver P) for a glass of weak "structural effect" (a) and strong "structural effect" (b).

In the case of glasses (a), a decrease of the annealing temperature is revealed by a shift of the polarimetric curve towards tension.

In the case of glasses (b), a decrease of the annealing temperature is revealed by a shift of the polarimetric curve towards compression.

For glasses having an expansion coefficient equal to that of the metal (α Glass $=$ α Metal) in the entire domain $T_s' - T_R$ the change in the annealing temperature would not modify the polarimetric curve.

These different results (variations in the opposite sense depending upon the "structural effect") explain that for many glasses that seal with Dilver P the effect of a modification of the annealing temperature upon the strain is relatively small.

The results described by Fig. 36b could be confirmed by an indirect method.

Ninety shipments of Dilver P were sealed in B2 sample form in three groups (540°, 510°, 480°) and cooled at a rate of 3"/min. In Fig. 37 the values of room temperature strains obtained after annealing at 540 and 480° are plotted against those obtained after annealing at 510°C., and found grouped around two lines with an incline of 45° and a correlation of .90.

This shows that the mean of the expansion curves of various supplies of Dilver P of recognized quality are such that:

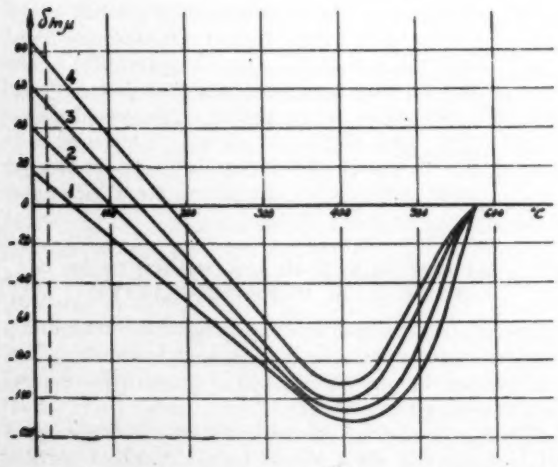


Fig. 38. Seal Molybdenum. — Glass A-119. — Sample B2. Influence of Rate of Cooling on Strain. (1) 10°/min.; (2) 3°/min.; (3) 1.5°/min.; (4) .75°/min.

(1) α Glass $\frac{Tr}{TS'}$ is larger than α Metal in the same ranges.

(2) In samples B2 an increase in annealing temperature by 30° over the normal causes a shift of room temperature strain by 2 millimicrons towards tension; a decrease by 30° a shift of 17 millimicrons towards compression.

Influence of the Holding Time tr at the Annealing Temperature Tr On the Strain. Many experiments have shown that when a hold of less than 20 minutes of B2 type samples at annealing temperatures normally assures relaxation of strain, holds of 20-60 minutes will give identical polarimetric curves. This time range corresponds to industrial practice.

Influence of Cooling Rate (v) on Strain.

The influence of cooling rate on sealing temperature has been studied. Now the influence on the entire polarimetric curve remains to be examined.

Metals of Constant Expansivity. Fig. 38 expresses the experimental results for the seal Molybdenum-Glass A-119, sample B2. The annealing temperature and time were maintained constant for four rates of cooling: 0.75°, 1.5°, 3°, 10°/min.

A decrease in cooling rate is revealed by: (a) A displacement of the polarimetric curve towards compression. (b) An apparent decrease of the expansion coefficient of glass below T_I, exhibited as an increase of the slope $d\delta/dT$ in absolute values.

The apparent difference of dilatation between the glasses cooled at 3°/min. and .75°/min. in the interval 20-300° can be calculated by the formulas previously established:

$$[\delta] = -BE_2 K (a - a_o) [d]$$
$$d\delta/dT = -BE_2 K (a - a_o) (\alpha \text{ Metal} - \alpha \text{ Glass})$$

In our case:

$[d\delta/dT$ (for rate .75°/min.) $-$ $(d\delta/dT)$ (for rate 3°/min.)$] = -BE_2 K (a - a_o)$ [$-$ α Glass (for rate 0.75°/min.) $+$ α Glass (for rate 3°/min.)]

which gives

α Glass for 3°/min. $-$ α Glass for .75°/min. $= .4 \times 10^{-7}$. This paradox result was confirmed by the successive elimination of experimental conditions liable to lead to doubtful conclusions.

Metals of Variable Expansivity. The experimental work was conducted as above. Fig. 39 expresses the results.

A decrease of rate of cooling is revealed by: (a) A general displacement of the polarimetric curve towards tension. (b) A decrease of the apparent expansion coefficient of glass below T_I.

Note. The results of (b) under *Metals of Constant Expansivity* and (b) above can be explained by the existence of α and β phases of glass, one stable at low, the other at high temperature. Slow cooling allows a large percentage of transformation to the low phase α, rapid cooling allows but a small percentage of this transformation. The observations then verify the difference in the coefficients of the phases.[4, 5]

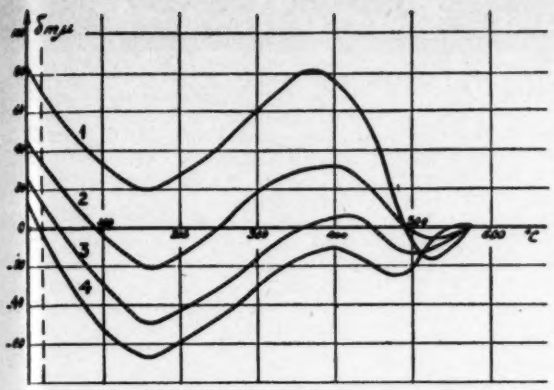


Fig. 39. Seal Dilver P — Glass L. Samples B2. Influence of Cooling Rate on Strain. (1) 10°/min.; (2) 3°/min.; (3) 1.5°/min.; (4) .75°/min.

The variations of rate of cooling, as existing in practice, are not overly important. In the cast of glass L-119 and Molybdenum the difference of α are for:

3° and .75°: $.4 \times 10^{-7}$

15° and 3° : $.5 \times 10^{-7}$

Conclusions. Establishment of the Optimum Annealing Cycle of Glass-Metal Seals

The effects of intrinsic variables of materials and annealing cycles shown by the preceding experiments are summarized in the following table:

POLARIMETRIC CURVE SHIFTS

Variable Elements	Metals of Constant Exp.	Metals of Variable Exp. Between Tr and TS':	
		α Met. $>$ α Gl.	α Gl. $>$ α Met.
		Glasses of Weak Structural Effect	Glasses of Strong Structural Effect
α Glass Low Range Increases	Shift to Tension		
α Glass High Range Increases			
Transf. Temp. T_g' Increases	Shift Follows Change of T_r with T_g'		
Annealing Temp. T_r Increases	Shift to Tension	Shift to Compression	Shift to Tension
Holding Time t_r Increases	No effect above 20 minutes		
Cooling Rate v Increases	(a) Shift to Tension (b) Decrease of $[\delta T_s - \delta T_1]$	(a) Shift to Compression (b) Decrease of $[\delta T_s - \delta T_1]$	

The existence of these effects shows that the annealing cycle for a given metal-glass pair must remain identical for all shapes because: (a) In fabricated pieces strain variations must derive only from changes in intrinsic material properties which also must be maintained within strict limits by appropriate controls. (b) Only then is it possible to find a correspondence between B and real shapes. This correspondence will be the subject of Part III of this study.

Now, the establishment of an optimum cycle of annealing becomes possible:

A. The annealing temperature and time are maintained as defined in *Definition of A Practical Optimum Annealing Temperature of Glass-Metal Seals.*

B. The cooling rates can be selected as in the case of glass alone (see *"Practical Shortest Cycles for Glasses in the Tube Industry"*), provided the seals remain within the same thickness limit.

To summarize: The practical optimum cycles will be:

	Ann. Temp. T_r	Holdg. Time t_r		Cooling Rate v
Hard Glass (α between 40 and 55 x 10^{-7})	$T_s + 1/3$ $(T_R - T_s)$	20 min.	below 3mm	Free cooling, from 550° 15°/min. max.
			3-12 mm	3°/min. to 300°, then free cooling
Soft Glass (α between 85 and 110 x 10^{-7})			below 2mm	Free cooling from 550°C. 15°/min. max.
			2-10 mm	3°/min. to 250° then free cooling

These cycles do not differ from those for glass alone, except for the annealing temperature. Since, in practice, most of the glass is handled with attached seal, the practical optimum cycle for glass-metal seals will be equally applied to glass pieces.

BIBLIOGRAPHY

2. F. Violet and A. Danzin—"Le Verre dans l'Industrie Radioelectrique", Annales de Radioelectricite, Janvier 1947.
4. Winter-Klein—Les bases physiques du recuit du verre, Bulletin de l'Institut du Verre, Mars 1946.
5. Jean Gillod—Contribution a l'etude experimentale des transformations structurales du verre. Nouvelle interpretation des courbes de dilatation et application a un recuit rationnel, Verres et Refractaires, Juin 1949.
9. Poritzsky—Physics 15, 1934 p. 406.
10. MM. Danzin et Vallentin—Articles non publies.
15. G. D. Redston, J. E. Stanworth—The Theoretical Development of Simplified Annealing Schedules, Journal of the Society of Glass Technology, Fevrier 1949.
16. G. D. Redston, J. E. Stanworth—Glass to metal seals, Journal of the Society of Glass Technology, Avril 1945.
17. L. H. Adams and F. D. Williamson—Annealing of Glass, Journal Franklin, Institute 190. 597.631 (1920).
18. J. C. Maxwell, Phil. mag. (4) *34* 129 (1868).

(To Be Continued)

LYNCH REPRESENTATIVE LEAVES FOR ENGLAND

The Lynch Corporation has announced that it has sent a representative to England to act as liaison engineer between the Lynch International, Ltd. and the Anderson, Indiana, factory.

Armand D. Norris, of the engineering department of the Glass Machinery Division of Lynch, will act in an advisory capacity to the new Lynch firm in England.

New Equipment and Supplies

NEW DECALCOMANIA TRANSFER

The Meyercord Company, 5323 W. Lake Street, Chicago 44, Illinois, has announced the development of Thermo-Cals, a new type of decalcomania for fusing onto glass or glaze quickly and easily. According to Meyercord's announcement, entirely new methods make possible quick application, easy and flexible positioning, and entirely new possibilities in extremely accurate, multi-color registration in a single firing.

The company further states that Thermo-Cals make possible for the first time complete ensembles involving both glass and chinaware; they lend themselves to extremely irregular shapes and to convex and concave surfaces where direct screening in many instances has been impossible; they provide a close approach to hand painted effects when desired; they are available in heavily opaque colors, as well as pastels; they eliminate the waiting period between application and firing; they eliminate the necessity for large storage and floor space for drying; they can be either acid or alkaline-proof.

NEW pH CONTROL UNIT

Analytical Measurements, Inc., 585 Main Street, Chatham, New Jersey, has introduced a new pocket-size pH meter and companion probe unit which permits instant, on-the-spot pH determinations anywhere.

Completely self-contained with batteries, the instrument is furnished, camera-fashion, in an every-ready case with plastic tubes of buffer and KCl solutions. Total weight is 3 pounds.

Supports and beakers are completely eliminated by combining the calomel and glass electrodes with the sample holder in a single polyethylene probe unit. The meter is scaled from 2 to 12 pH for easy reading, and a simple adjustment gives readings from 0 to 14. Accuracy of 0.1 pH is obtainable. Hearing-aid type batteries provide up to 1300 hours of operation. The electrometer tube, switch and input connector are sealed in a single unit to ensure freedom from high humidity difficulties. Grounded samples can be directly measured because of no external power connections.

NEW TORCH FOR CAMERA AND OPTICAL LENS WORK

Weldit, Inc., Detroit, Michigan, has announced a new Weldimatic torch for use in camera and optical lens work.

The torch is employed in melting the adhesive which attaches camera lens to a spindle on a grinder. Fueled with either natural or propane gases, the torch is said to be faster than old methods, with greater economy of both time and fuel.

WALSH MULLIFLUX

Walsh Refractories Corporation, 101 Ferry Street, St. Louis 7, Missouri, has made available Walsh Mulliflux, vacuum cast sidewall and bottom blocks for glass melting furnaces.

The result of years of experimentation and testing that began during World War II, Walsh's new product is said to be qualified to successfully cope with the most severe service conditions encountered in modern glass melting practice. Greater density, more uniform expansion, and superior resistance to high temperatures and corrosion are said to be the outstanding characteristics of the new refractory block. The block is machine-trued to exact size and shape after burning at extremely high temperatures. As an added advantage, distinctive markings on each block readily identify Cast Mulliflux: B for Bottoms and S for Sidewalls.

TWIN SHELL BLENDER

The Patterson-Kelley Company, Inc., 376 Burson Street, East Stroudsburg, Pa., has announced the development of a Twin Shell Blender.

The blender consists of two equal-diameter cylindrical shells which are joined to form a V. It rotates around a horizontal axis which passes through the geometrical center. A dust-tight discharge valve is located at the point of the V. Standard access covers with swing bolts and dust-tight gaskets are located at the end of the two legs. If all dust must be avoided while loading, the machine can be set in the inverted V position and fed through the discharge valve at the apex of the V.

DEVICE FOR AUTOMATICALLY COMPILING AND PLOTTING

Minneapolis - Honeywell Regulator Company, Brown Instruments Division, Wayne and Windrim Avenues, Philadelphia 44, Pa., has announced a new electronic instrument for the automatic compiling of two measurements and plotting of a curve to show their interrelationship; namely, Y equals f (X).

The instrument is said, by the division's engineers, to incorporate two measuring systems, one of which actuates the recorder pen while the other motivates the instrument chart. With this arrangement, according to the announcement, the chart is driven up and down in response to the changes in one variable simultaneously with the movement of the pen in response to changes in a second variable. The result is a curve which continuously evaluates one variable in terms of the other.

CATALOGS RECEIVED

Eveready BrikSaw Company, 1509 South Michigan Blvd., Chicago 5, Illinois, has issued a new booklet, entitled "How to Cut Blade Costs in Masonry Cutting" and designated as Booklet 101, which gives practical, illustrated instructions on how to figure blade costs in masonry cutting before starting full cutting operations.

The booklet is intended for use of the contractor or operator and, among the information contained, are the following facts: How an operator can run his own simple blade cost analysis tests before starting the job; How abrasive blades and how diamond blades are manufactured; When to use an abrasive blade and when to use a diamond blade; How to tell if a blade is too soft or too hard for a certain material; How to know the exactly correct abrasive or diamond blade to use on each different material.

Jervis B. Webb Company, Detroit, Michigan, has announced Catalog No. 51 devoted to its new floor type conveyor.

The catalog contains 90 pages of information on conveyor chains, Chain-On-Flat, and Chain-On-Edge Floor Conveyors with a variety of pusher dogs used in connection with them. Also typical drive and takeup ends, sprocket and roller turns, cross sections, curves, inclines and declines which are used in these conveyor systems are discussed.

Minneapolis-Honeywell Regulator Company, Industrial Division, Wayne and Windrim Aves., Philadelphia 44, Pa., has issued a condensed Catalog of Furnace and Oven Controls, Catalog 51-1.

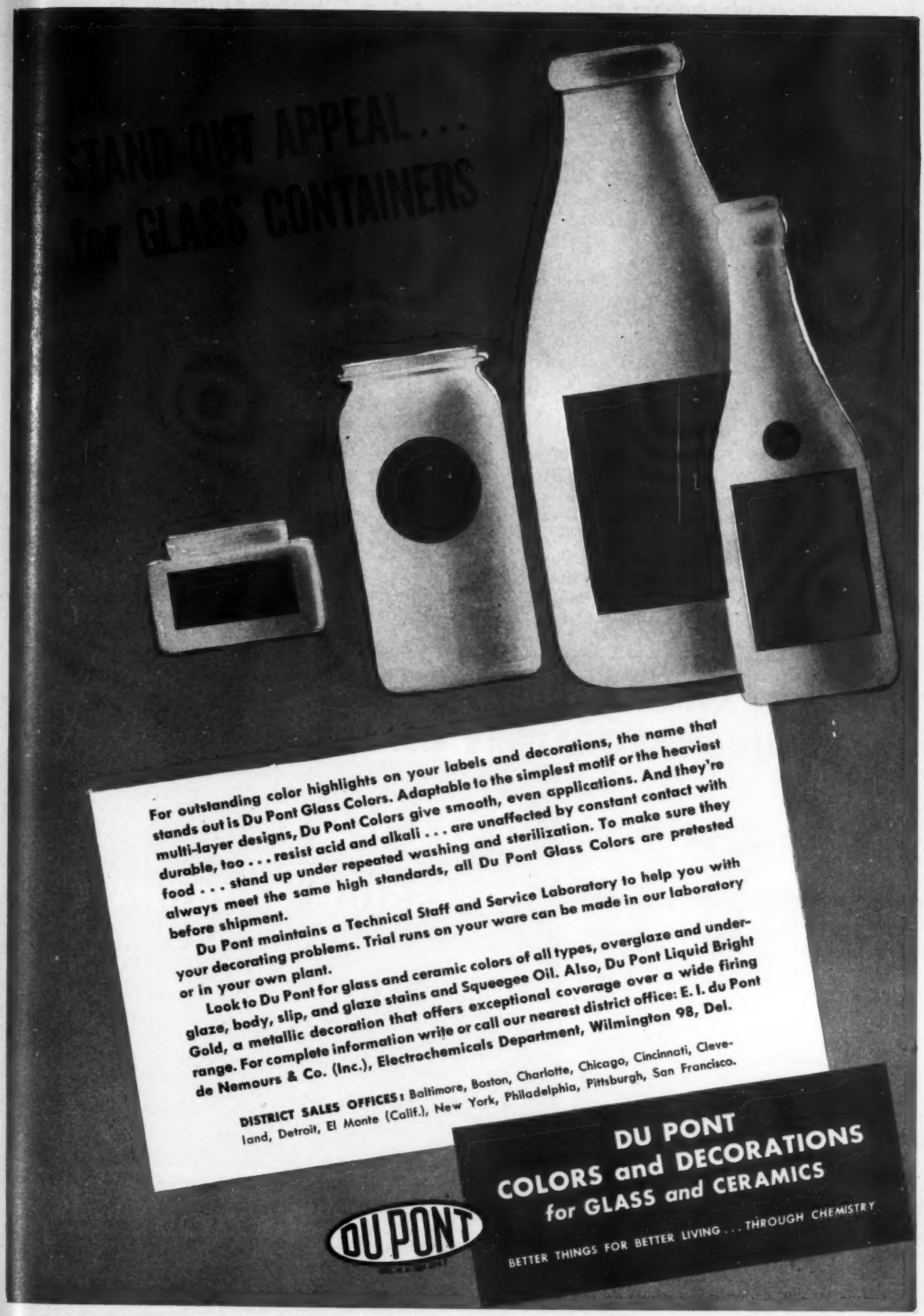
The 28-page catalog lists and prices a variety of instruments such as temperature controllers, recorders and indicators; electric and pneumatic operated control valves; relays; control motors; safety control equipment generally used in the temperature control of ovens and furnaces.

Baldwin - Lima - Hamilton Corporation, Philadelphia 42, Pa., has announced the publication of its new 2-page bulletin, No. 174, devoted to SR-4 Temperature-Compensated Strain Gages.

The bulletin shows graphic performance and gives specifications for ten new type SR-4 resistance wire strain gages. These gages are only slightly affected by temperature variations within certain ranges when bonded to steel or aluminum.

Fisher Scientific Company, 717 Forbes Street, Pittsburgh 19, Pa., has published a six-page folder which illustrates and describes the scientific instruments, laboratory apparatus, and safety devices it has developed and introduced during the past two years.

The folder lists 37 new items which have been made available since the company published its most recent catalog supplement.



For outstanding color highlights on your labels and decorations, the name that stands out is Du Pont Glass Colors. Adaptable to the simplest motif or the heaviest multi-layer designs, Du Pont Colors give smooth, even applications. And they're durable, too . . . resist acid and alkali . . . are unaffected by constant contact with food . . . stand up under repeated washing and sterilization. To make sure they always meet the same high standards, all Du Pont Glass Colors are pretested before shipment.

Du Pont maintains a Technical Staff and Service Laboratory to help you with your decorating problems. Trial runs on your ware can be made in our laboratory or in your own plant.

Look to Du Pont for glass and ceramic colors of all types, overglaze and underglaze, body, slip, and glaze stains and Squeegee Oil. Also, Du Pont Liquid Bright Gold, a metallic decoration that offers exceptional coverage over a wide firing range. For complete information write or call our nearest district office: E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Department, Wilmington 98, Del.

DISTRICT SALES OFFICES: Baltimore, Boston, Charlotte, Chicago, Cincinnati, Cleveland, Detroit, El Monte (Calif.), New York, Philadelphia, Pittsburgh, San Francisco.

DU PONT
COLORS and DECORATIONS
for GLASS and CERAMICS

BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY

DU PONT

BENJAMIN WOODS JOINS WILLIAM ESTY COMPANY

Benjamin Wood, formerly Director of Advertising and Marketing of the Glass Container Manufacturers Institute, has resigned to become a Vice President and a member of the Plans Board of the William Esty Company, Inc.

Prior to Mr. Wood's association with the Glass Institute, he was for 11 years Managing Director of Tea Bureau, Inc. Mr. Wood will assume his new duties June 1.

BOOK REVIEW

Basic Refractories
By J. R. Rait

This book includes a description of original research carried out by the author from 1938 for which he was awarded the degree of Doctor of Science.

It contains a review of our fundamental knowledge relating to basic refractories including dolomite, magnesite, chrome-magnesite, and forsterite. The establishment of the complex phase diagram $CaO\text{-}MgO\text{-}SiO_2\text{-}Al_2O_3\text{-}Fe_2O_3$ and the derivation of the constitution of numerous commercial basic refractories from various countries are described.

Chrome ores have also received detailed attention. Basic refractories under various service conditions such as basic open hearth roofs, electric furnace hearths and side walls have been subjected to detailed examination; the modes of falure are described; and a new theory to account for the flaking of basic refractories proposed.

NORTON NAMES MANAGER GRINDING MACHINE DIVISION

Robert D. Lawson has been named Sales Manager of Norton Company's Grinding Machine Division, according to an announcement by Frank W. Smith, Vice President.

Mr. Lawson, Chicago district manager for the company's Grinding Machine Division since 1946, will replace C. Denson Day, who has resigned. Joining Norton in 1918, Mr. Lawson worked through various phases of machine sales until his appointment as Chicago district manager five years ago.

LACLEDE-CHRISTY PURCHASES FIRE BRICK COMPANY

A. B. Agnew, Vice President and General Manager of Laclede-Christy Company, has announced that the company has purchased the plant and physical assets of Paterson Fire Brick Company at Clearfield, Pa.

The plant specializes in famous Clearfield County stiff mud clay refractory brick. Additional facilities will be added immediately to help produce the urgently needed refractories to aid the war effort in steel production and similar requirements.

For Fine Glass ...
for Quality **LABORATORY GLASSWARE**

SOLVAY

POTASSIUM CARBONATE

Dustless Calcined
Potassium Carbonate
99-100% K_2CO_3

Granular Hydrated
Potassium Carbonate
83-85% K_2CO_3

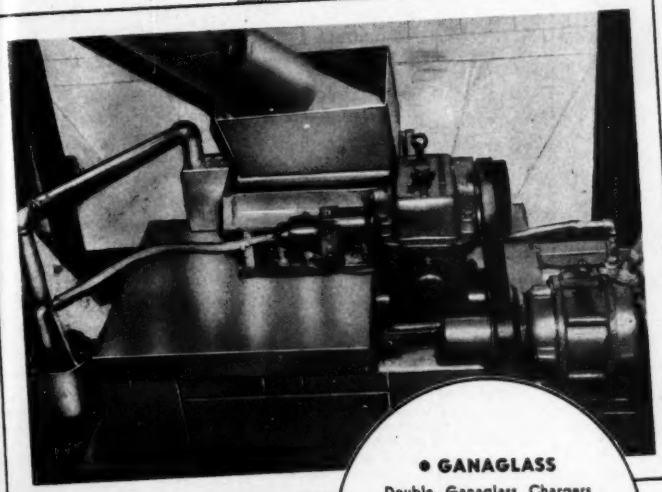
Always specify Solvay **Potassium Carbonate for Fine Optical Goods**
Fluorescent Tubes • Stemware • Laboratory Glassware

SOLVAY SALES DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

BRANCH SALES OFFICES:
Boston • Charlotte • Chicago • Cincinnati • Cleveland • Detroit • Houston
New Orleans • New York • Philadelphia • Pittsburgh • St. Louis • Syracuse

THE GANAGLASS AUTOMATIC BATCH CHARGER

The GANAGLASS automatic batch charger was developed to fill a definite need in the modern glass industry for an automatic batch charger that would incorporate the following:



• GANAGLASS

Double Ganaglass Chargers are installed in tanks pulling 100 tons daily and up, in the United States. Single Ganaglass Chargers are installed in tanks pulling from 5 tons to 100 tons daily extraction, in the United States and abroad.

- Lower glass melting costs, through easily regulated and controlled batch feeding, and sealing-off of furnace dog-house.
- Ruggedly built, of modern design, yet with a reduced number of parts to simplify operation and maintenance, and minimize wear.
- Instantaneous regulation while operating.
- *Adaptable to large and small tank furnaces, either side port or end port fired.
- Easily installed in conventional type dog-houses, without the necessity of purchasing a large number of "special shapes".
- Economical to operate.
- Low in purchase cost.

The GANAGLASS automatic batch charger incorporates and meets the above requirements. It has been thoroughly tested in the glass industry in the United States for a number of years, and is today giving satisfactory service. Foreign installations have also been made • We would welcome the opportunity of adapting this batch charger to your needs.

• • •

Complete installations for the manufacture of bottles, tableware, window glass, tubing, and fiber, erected and in operation in various parts of the world. Glass melting tank furnaces, gas or oil fired • Automatic tube and rod drawing machines • Annealing lehrs, oil or gas fired • Automatic batch chargers • Automatic bottle blowing machines • Glass fiber drawing machines • Automatic lehr loaders.

GENERAL GLASS EQUIPMENT CO.

ATLANTIC CITY, NEW JERSEY

AVOID COSTLY DAMAGE

BROWN INSTRUMENTATION IS THE Plus-Factor

To Furnaces and Workloads

. . . WITH THE

PROTECT-O-VANE

EXCESS TEMPERATURE

SAFETY CUT-OFF CONTROLLER

MANY installations, where temperature is a factor in processing, are running the risk of serious damage from excess temperatures resulting from equipment failure. The cost can be considerable . . . expensive furnace repairs . . . a ruined work load . . . loss of valuable production time!

The *Protect-O-Vane* is daily providing inexpensive insurance against loss due to excess temperatures, in many hundreds of industrial plants. It automatically cuts off the power and/or the fuel supply if the safe temperature limit is exceeded. Simultaneously, a warning signal is given by means of a flashing neon light mounted on the front of the instrument . . . and by an audible alarm, if desired.

It Costs So Little to Protect So Much! The *Protect-O-Vane* is most reasonably priced, and gives proved protection against failures which could be so expensive. It can be used with any type of controller, or alone, and is applied to all types of furnaces, ovens and other heating equipment.

Call in your local Honeywell engineer for a discussion of its value in your plant . . . he is as near as your phone. MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4521 Wayne Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

Check These Performance Features!

- √ Reset must be manual, by means of button on front of case, and is not effective until temperature drops to safe point.
- √ "Fail-Safe" design . . . flashing neon light warns of component failure.
- √ Thermocouple burn-out protection is standard equipment.
- √ Instantaneous action . . . provided by electronic control unit and snap-acting 5 or 30-ampere load relay.
- √ Easily read 6" wide scale in compact 9" wide case . . . interchangeable for flush or surface mounting.

For Complete Information Write for Specification No. 113.

MINNEAPOLIS **Honeywell**

BROWN INSTRUMENTS

TARIFF AND IMPORT STATISTICS

A summary of the imports by principal sources of table, stem, and art glassware for 1950 and 1949 has been prepared by the U. S. Tariff Commission. The imports for 1950 are the largest since 1935 and it is shown that Czechoslovakia is the largest exporter of this ware for both 1949 and 1950. Notable increases were made by Italy, France, Germany, and Japan.

Blown Table and Art Glassware, Hand-Made only: United States Production and Imports, in Specified Years, 1935 to 1950

(Value of imports is foreign value)

Year	Production [1] 1,000 dollars	Imports for Consumption [2] 1,000 dollars	Ratio of imports to production [3] Percent
1935	8,000	1,440	18
1937	9,900	2,640	27
1939	7,100	1,370	19
1943	13,500	240	2
1945	18,200	400	3
1946	23,000	1,800	8
1947	23,000	2,300	10
1948	22,000	2,100	10
1949	19,500	2,250	12
1950	16,000	2,700	17

[1] Estimated.

[2] Obtained by deducting estimated amounts of glass jewelry, television tubes, and pressed ware from total imports of pressed and blown glassware as reported in the official statistics.

[3] The ratios based on landed value of imports (foreign value plus duty and transportation costs) would be nearly doubled.

Source: Industry Reports and official statistics of the U. S. Department of Commerce.

Table and art glassware:[1] United States imports for consumption,[2] by principal sources, in 1949 (total and monthly average) and 1950 (total and monthly average).

Source	1949 Total	1949 Monthly average	1950 Total	1950 Monthly average
All countries				
Number of pieces[3]	12,071,991	1,006,000	23,668,324	1,972,360
Unit foreign value[3]	$0.234	$0.234	$0.136	$0.136
Total foreign value	$2,940,457	$245,038	$3,453,756	$287,811
Principal sources				
Czechoslovakia	$478,241	$39,853	$460,077	$38,340
United Kingdom	404,678	33,723	402,245	33,520
Sweden	257,632	21,469	268,620	22,385
Belgium	214,846	17,904	259,882	21,657
Italy	187,116	15,593	284,760	23,730
France	184,130	15,344	256,896	21,408
Germany	113,497	9,458	306,133	25,511
Portugal	88,139	7,345	10,633	886
Netherlands	113,390	9,450	132,506	11,042
Finland	52,781	4,398	51,618	4,302
Japan	205,405	17,117	332,835	27,736
Poland	106,778	8,898	99,651	8,304
Hungary	91,313	7,609	73,945	6,162
Canada[4]	353,488	29,458	384,554	32,046
All other	89,023	7,419	129,381	10,782

[1] Covers imports under tariff paragraphs 218(d), 218(f) (except Christmas tree ornaments), 218(g), and certain classes under 230(d), all of which consists largely of table and art glassware.

[2] Preliminary.

[3] About 10 percent (by value) of all imports are not reported by quantity and are therefore excluded from these data.

[4] Imports consist largely of glass television tubes.

Source: Official statistics of the U. S. Department of Commerce.

VOLUME DILATOMETRY . . .
(*Continued from page* 233)

The preparation and operation of the volume dilatometer may be described briefly as follows: A glass capillary is carefully calibrated and sealed to one end of a larger glass tube. The weighed sample is introduced into the tube, a glass bulb is added, and the tube is sealed. The bulb is used to prevent overheating of the sample during the sealing operation. The dilatometer is then weighed, evacuated, filled with mercury, reweighed, and then placed in a bath. As the bath is heated, the sample expands, forcing mercury up into the capillary where readings may be made. From the known weights and densities of the sample and the confining liquid and from the known expansivity of the confining liquid, the expansivity of the sample can be calculated. Corrections must be applied for entrapped air bubbles, nonuniformity of the capillary, and the thermal expansion of glass.

WEST COAST A.C.S. SECTION HOLDS MEETING

The Southern California Section of the American Ceramic Society featured as speaker at its recent meeting Chad Dillon, Manager of Quality Control, Latchford-Marble Glass Company. Mr. Dillon headed a panel discussion on production problems.

The mechanics of bottle forming was stressed and particular emphasis was placed on the importance of gob shape, mold design, glass temperature, mechanical limitations, and operating practices. There was much discussion from the audience and a desire was expressed for a continuation of this general subject at a later date.

ABSENTEEISM ADVISORY COMMITTEE FORMED

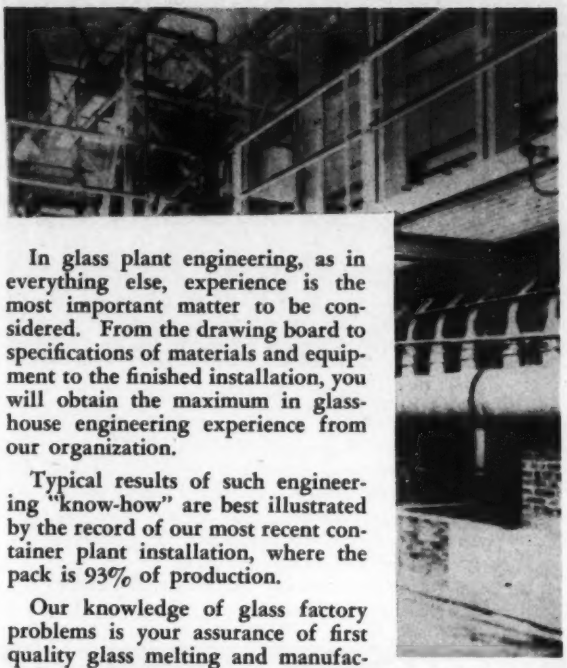
The National Institute for the Reduction of Industrial Absenteeism has announced the formation of an advisory committee composed of many national organizations.

The Institute, a non-profit research organization set up under the laws of the State of New York, will function on a membership basis, and will provide an immediate source of data and information on the subject of absenteeism. The information will be disseminated to its members through the medium of a monthly research bulletin and a quarterly journal on industrial absenteeism.

SECTION MEETINGS OF THE A.C.S.

The Trenton Section of the American Ceramic Society featured Robert E. Gould, President and General Manager of Buffalo Pottery, Inc., as speaker at its early spring meeting. Mr. Gould's subject was "Mechanization in Whiteware Plants" and, during his talk, he brought out many interesting problems his company had encountered when it turned to mechanization. The Section is planning a Grinding Symposium for its May meeting.

Dr. Games Slayter, Vice President in Charge of Research at Owens Corning Fiberglas Corporation, was the speaker at a recent meeting of the Central Ohio Section. Dr. Slayter spoke on the subject "Potential Ceramic Modulus Combinations". The possibilities of extending high modulus and low modulus component combinations into ceramics and other fields were discussed.



In glass plant engineering, as in everything else, experience is the most important matter to be considered. From the drawing board to specifications of materials and equipment to the finished installation, you will obtain the maximum in glass-house engineering experience from our organization.

Typical results of such engineering "know-how" are best illustrated by the record of our most recent container plant installation, where the pack is 93% of production.

Our knowledge of glass factory problems is your assurance of first quality glass melting and manufacturing equipment, as well as top service and performance.

We will be glad to consult with you.

HENRY F. TEICHMANN, INC.

INVESTMENT BUILDING — PITTSBURGH 22, PA.
Telephone: COurt 1-6210 — *Cable:* HEFTINC

POLARISCOPES
for
Qualitative Observation

•

POLARIMETERS
for
Quantitative Measurement

•

POLARIZING INSTRUMENT CO., Inc.
273 N. Bedford Road
Mt. Kisco, N. Y.

In the annealing and decorating of glass and ceramics, Wissco Metal Processing Belts have attained outstanding leadership because of their proved advantages. Their patented mesh construction assures free air circulation for more uniform heat treatment—presents limited surface contact with the ware, thus eliminating strain and bottom cracking.

Available in all desirable weaves and alloys including one, two, or three per cent chrome steel types.

Write for illustrated booklet describing types and cost-cutting advantages of Wissco Belts.

WISSCO METAL PROCESSING BELTS CF&I

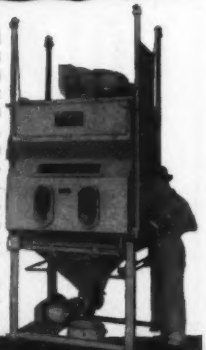
A PRODUCT OF WICKWIRE SPENCER STEEL DIVISION OF THE COLORADO FUEL & IRON CORPORATION
Sales Office and Plant—56 Sterling Street, Clinton, Massachusetts
Executive Office—500 Fifth Avenue, New York 18, New York
Sales Offices—Atlanta • Boston • Buffalo • Chicago • Denver • Detroit • New York • Philadelphia
Pacific Coast—The California Wire Cloth Corporation, Oakland 6, California

Hydro-Finish *Speeds Up* Polishing of Glass Molds

VIRTUALLY ELIMINATE all hand cleaning and polishing of glass molds with Pangborn *Hydro-Finish!* Cleans molds faster than other methods yet holds tolerances. Maintains sharp edges and contours, leaves molds ready for use.

Complicated molds or designs are easily cleaned *throughout* because Hydro-Finish uses fine-mesh abrasives suspended in water, impelled through controlled feed. By holding tolerances to .0001, Hydro-Finish substantially increases life of molds.

FREE: Write for Bulletin 1400-A to: PANGBORN CORP., 3400 Pangborn Blvd., Hagerstown, Maryland.



Pangborn
BLAST CLEANS CHEAPER
with the right equipment for every job

RESEARCH DIGEST . . .
(*Continued from page* 251)

This report deals with the results obtained during a study of glass mold lubricants.

The critical adherence test as applied to glass mold lubricants differs slightly from the test when it is used to find T_c (critical adherence temperature) for uncoated metal samples. The exception is that lubricants are sprayed or swabbed on the surface of the metal sample immediately before each molten bead strikes the metal surface. With this type of test the lubricant deposits a layer of material on the surface which supposedly prevents the molten glass from adhering.

The critical adherence temperature alone does not qualify the use of the lubricants. Some lubricants are flammable, some form heavy deposits which flake easily and could change the internal dimensions of the mold. A few may have noxious odors, while others may have only a short life at the temperatures encountered in glassware manufacture. Thus, it was necessary to test the lubricants further for their persistence and suitability.

The persistence test was devised in order to determine the length of time the lubricants will remain on the metal surface and prevent glass from adhering. This test is a modification of the standard critical adherence test and it was performed as prescribed in the following procedure: (1) the metal sample was raised to a constant temperature; (2) between 0.05 to 0.10 gm. of lubricant was applied to the surface of the metal sample; (3) molten glass beads were dropped on to the lubricated surface at intervals of approximately one minute until

AMCO

Design, Erection and Operation of Manufacturing Plants and Furnaces for All Types of GLASS WARE

AMSLER MORTON CORPORATION
CHAMBER OF COMMERCE BUILDING, PITTSBURGH 19, PA.

the glass beads adhered; (4) the adherence time of each molten bead was noted. The time interval between the application of the lubricant and the dropping of each glass bead was recorded and designated as the cumulative time. A plot was made of the adherence time vs. the cumulative time; (5) the persistence time was defined as the cumulative time between the application of the lubricant and the beginning of bead adherence. The latter was determined from the plot of adherence time for each bead vs. cumulative time.

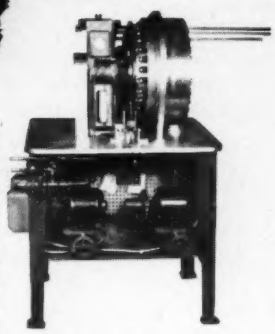
Only a few of the lubricants whose critical temperatures were determined were tested for their persistence time. Those not tested either had low critical adherence temperatures or formed thick deposits on the surface of the metal sample when tested for their maximum adherence temperature.

The five suitability characteristics of the various mold lubricants which were tested are shown in Table I. It was found that lubricants containing free graphite were superior to any other type even though the critical adherence temperatures of silicone lubricants were higher. Those silicones which have high critical adherence temperatures contain a large percentage of silicone which decomposed upon heating leaving a thick, white flaky layer deposited on the metal surface.

• The Hays Corporation has announced the appointment of Orval M. Riggs to the position of Manager, Application Engineering. In his new position, Mr. Riggs will work closely with customers to develop further applications of the Hays line of combustion and industrial instruments and controls.

KAHLE
specialists
in custom built
glass-making
machinery

#1507
HIGH SPEED AUTOMATIC
GLASS TUBING CUTTING
MACHINE



All Kahle equipment is custom-made — we don't turn out *stock* machinery. That's why we can do a better job for you — all our engineering skill and experience is concentrated on your specific glass manufacturing or finishing problem.

High production on specific diameters. 30 head, continuous drive. Variable speeds. Length of cut adjustable. 7500-15,000 pieces per hour.

We're Specialists in equipment that cuts costs, increases production, assures uniformity in the manufacture of: ampules • cathode ray tubes • standard, miniature, sub-miniature radio tubes • sub-miniature tubes • fluorescent lamps • incandescent lamps • photocells • x-ray tubes • glass products.

Consult Kahle! There's no obligation. Write for our complete, new catalog today!

Kahle ENGINEERING COMPANY

1308 Seventh Street
North Bergen, New Jersey, U. S. A.

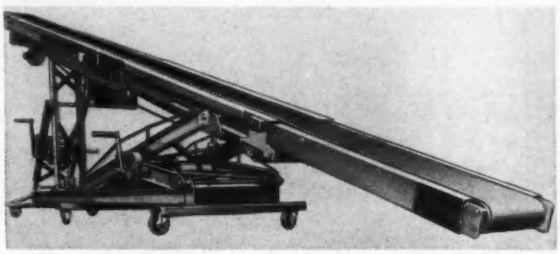
GLASS
COLORS

BETTER ACID
RESISTANCE

BETTER ALKALI
RESISTANCE

FASTER FIRING
BETTER COVERAGE
MAXIMUM BRILLIANCE
PERMANENT SUSPENSION

O. HOMMEL CO.
PITTSBURGH 30, PENNA.



The NEW ADJUSTOVEYOR
is 10 different conveyors in one!

One Adjustoveyor does the work of 10 different conveyors — yet one price pays for all its many adaptations and uses! Adjustoveyor moves easily, and can be placed exactly where it's needed. It is suitable for all types of material handling in packages or loads, and will stack between floors or in piles. Adjustoveyor is an investment in the future —it grows right with your plant. When your plant or processes change, Adjustoveyor changes right with them! Complete range of models and lengths available, permitting standard units to exactly fit your factory requirements. WRITE FOR DETAILS TODAY!

STEWART-GLAPAT Corp.
1639 Moxahala Avenue, Zanesville, Ohio